SOUTH ATLANTIC OCS AREA LIVING MARINE RESOURCES STUDY

VOLUME II

DISCLAIMER

FINAL REPORT

SOUTH ATLANTIC OCS AREA
LIVING MARINE RESOURCES STUDY

VOLUME II

AN INVESTIGATION OF LIVE BOTTOM HABITATS NORTH OF CAPE FEAR, NORTH CAROLINA

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ABSTRACT

During the late summer of 1980, three live bottom areas on the continental shelf off North Carolina were sampled to characterize these habitats in terms of relief, geographic extent, and percent sediment cover; assess demersal fish community structure in terms of species composition, abundance, and diversity; assess benthic epifauna and macroalgal populations in terms of species composition, abundance, biomass, diversity, and geographic affinities; describe trophic relationships among live bottom organisms by analyzing stomach contents from reef fishes; and collect hydrographic and meteorological information.

The three designated study sites were located (1) approximately 18.5 km northeast of Cape Hatteras (inner shelf, IS04) in a 19 - 27 m depth zone; (2) approximately 37 km southeast of Cape Fear (middle shelf, MS04) in a 27 - 55 m depth zone; and (3) approximately 46 km east-southeast of Ocracoke Inlet at the edge of the continental shelf (outer shelf, OS04) in a 55 - 100 m depth zone. Gear included fathometer, underwater television and still-photo cameras, suction and grab samplers, dredge, trawl, speargun, rod and reel, longline, fish trap and juvenile fish sled.

Flora and fauna of the live bottom communities were found to be very diverse. Among the three study areas, large variations in abundance and composition of organisms reflected differences in sediment load and rock relief and possibly geographic location and depth of these areas. The large number of tropical and subtropical species collected at MS04 indicates that this area represents a northward extension of a Caribbean biogeographic province; species collected at IS04 and OS04 were characteristic of the Virginian Province. Within a site, species abundance and diversity were positively correlated with relief of the area and the number of ledges and crevices.

Results of the nektonic studies indicated that diversity of fish species caught by trawls at the middle shelf station depended on time (day or night) of trawling. Diversity at this station was greater than at the inner shelf station possibly because trawling at MS04 was done over rocky live bottom while trawling at IS04 was done over sand bottom. No trawls were made at OS04 due to high relief. Most of the fish sampled appeared to be generalized predators, feeding on motile and sessile epibenthic invertebrates associated with the live bottoms.

CHAPTER 1

INTRODUCTION

BACKGROUND

Live bottom areas associated with sedimentary rock outcrops are a common feature of the continental shelf off North Carolina. These areas, which support a highly diverse flora and fauna, have been identified by the Bureau of Land Management (RF #AA551-RP9-10) as critical habitats of economic importance to both sports and commercial fisheries of the southeastern United States. The research results described in this report were gathered to further our understanding of the importance of these areas, particularly as they relate to physical habitats, biological characteristics and food webs associated with significant fisheries. The synthesis of the data gathered in this project in combination with the results of previous investigations will provide information to the Department of Interior for its management decisions associated with the leasing and exploration of tracts on the continental shelf for hydrocarbon resources.

The live bottom areas off North Carolina are part of a larger biogeographical province which extends from Cape Hatteras, North Carolina, to Cape Canaveral, Florida. This province is defined on its seaward edge by the Gulf Stream. The biological nature of this province is controlled to a large extent by the Gulf Stream flowing northward combined with a diffuse current flowing southward inshore of the Gulf Stream. The characteristics and circulation of these waters have been described in great detail (Environmental Research and Technology, Inc. 1979). With reference to the biology of hard bottom areas off North Carolina, the two most important characteristics of this circulation are (1) the periodic subsurface transport of nutrient rich waters onto the continental shelf from slope waters and (2) horizontal meanders and eddies of the Gulf Stream over the continental shelf. The transport of nutrient rich waters supports the relatively high primary productivity over the continental shelf that results in increased biomass of phytoplankton in the water column and, where water clarity permits (Onslow Bay), abundant attached macroalgae on the bottom. The phytoplankton productivity in turn serves as a basic food resource for suspension feeding animals which occur in great diversity and high density attached to the rock surfaces. The attached macroalgae is important to a variety of motile, grazing animals associated with hard bottoms. Commercially important fish feed at various trophic levels in this community but basically depend on the primary productivity of the phytoplankton and macroalgae. The meanders and eddies of the Gulf Stream over the continental shelf are thought to be critical to maintenance of the high diversity of live bottom communities by transporting larval stages and spores of tropical species into what would ordinarily be considered a temperate ecosystem. Although not yet well documented, this periodic source of recruitment apparently has resulted in a northward extension of a tropical/subtropical community normally associated with coral reefs in the Caribbean.

A large body of literature is developing which describes the physical, geological, and biological characteristics of the live bottom systems on the continental shelf off the South Atlantic coast of the United States. The best summary of this information to date has been prepared by Continental Shelf Associates, Inc. (1979) in a report entitled "South Atlantic Hard Bottom Study." The introduction to that report reviews all pertinent literature, with sections on geology (and topography) and biology, and a division of the shelf into three depth zones: inner shelf (15 - 25 m), middle shelf (30 - 40 m), and outer shelf (50 - 80 m). In the investigation reported here these zones have been defined as: inner (19 - 27 m), middle (27 - 55 m) and outer (55 - 100 m). Since the exhaustive review by Continental Shelf Associates, Inc. (1979) is available, no further literature review will be made in this report except in discussion of specific results.

PROJECT ORGANIZATION

General Information:

The "Investigation of Live Bottom Areas on the Continental Shelf of North Carolina" was subcontracted through the South Carolina Marine Resources Research Institute (SC MRRI) to the Duke University Marine Laboratory (DUML) which is an interdepartmental/interdisciplinary facility of Duke University dedicated to teaching and basic research in marine sciences. Much of the early research at the Marine Laboratory consisted of determining the distribution of plants and animals within the varying environments of the coastal waters. With the addition of the Cooperative Oceanographic Program and the expansion of year-round activities, the general theme of relationships of animals and plants to their environment has been broadened to include all segments of the estuarine and oceanic environments. Year-round research by resident staff, associates, visiting staff, and graduate and undergraduate students generally falls into seven broad disciplines: environmental health, biochemistry, botany, developmental biology, oceanography, physiology, and systematics-ecology. The Marine Laboratory is a part of Duke University and as such operates under the policies, procedures, and regulations of the University.

Management Structure:

Responsibility for the execution of the North Carolina project was held by the principal investigator, Dr. William W. Kirby-Smith, supported by a staff of key personnel. Management structure for the North Carolina project is shown in Figure 1.1. Dr. Kirby-Smith directed all phases of the effort from the initial organization, hiring of project personnel, logistics of field sampling, supervision of laboratory activities and data management to the preparation of the final report. As North Carolina coordinator, Dr. Kirby-Smith served as the contact between the DUML group and SC MRRI.

Dr. Richard Searles, Duke University, was responsible for the diving program. He also assisted by identifying some of the collected algae. Dr. Paulette Peckol, DUML, was responsible for analysis of video tapes, photographs, and quantitative benthic samples. She also served as chief scientist on the R/V Eastward cruise, participated in the diving program, and assisted by identifying collected algae and invertebrates. Mr. Robert Matheson, DUML, was responsible for the fishery research efforts in this project from catching of fish through interpretation of data. He also served as chief scientist on the R/V Dan Moore cruise. Mr. Steve Ross, North Carolina Division of Marine Fisheries, was responsible for the fisheries data collection on the diving trips and assisted Mr. Matheson by identifying some of the fish collected.

Further assistance in the identification of invertebrates was received from the following consultants:

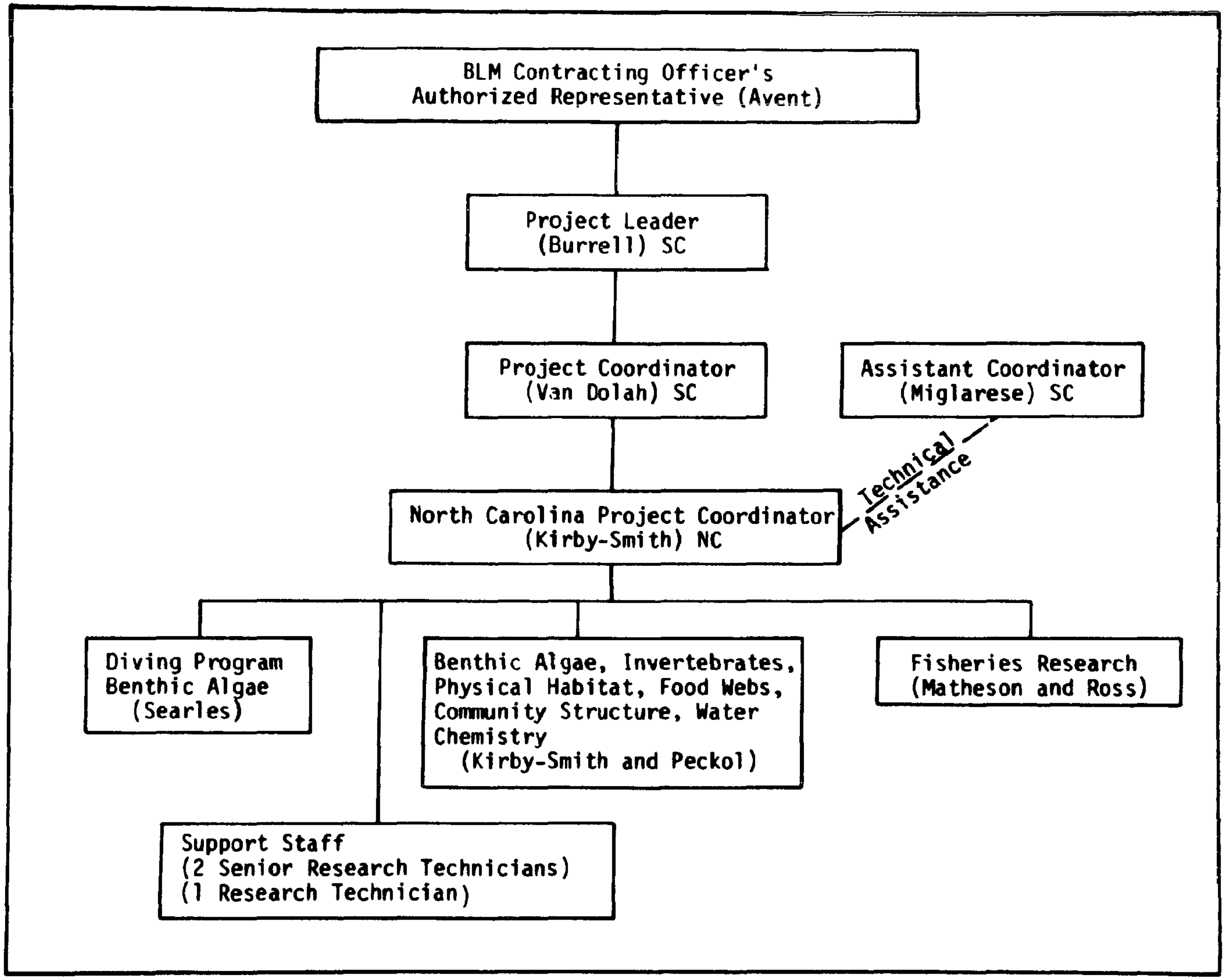

Figure 1.1. Management structure.

D. Pawson, Curator, Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution (Holothurians);

H. Porter, University of North Carolina Institute of Marine Sciences (Molluscs);

G. Hendler, Smithsonian Oceanographic Sorting Center, National Museum of Natural History, Smithsonian Institution (Ophiuroids).

In addition to the key personnel mentioned above, the North Carolina group included two senior research technicians and one research technician.

Cruise Participants:

On the R/V Eastward cruise, five participants were members of the DUML BLM project team and two were from the SC MRRI BLM group. They were assisted by seven students or staff members of DUML. On the R/V Dan Moore cruise, two DUML BLM project team members were assisted by one SC MRRI BLM member and the ship's crew.

GENERAL OBJECTIVES

The purpose of the investigations reported here was to extend the existing "South Atlantic OCS Area Living Marine Resources Study" contracted by SC MRRI to the continental shelf off North Carolina. The specific objectives and limitations are described in the following paragraphs.

Areas Sampled:

Previous research on South Atlantic live bottoms (summarized by Environmental Research and Technology, Inc. 1979) has suggested that major changes occur in the fauna and flora of live bottoms as depth increases, while latitudinal differences are much less pronounced. For this investigation three depth zones were identified: inner shelf (19 - 27 m), middle shelf (27 - 55 m) and outer shelf (55 - 100 m). At each depth zone one live bottom area was selected for intensive study with the objective of characterizing the invertebrate and nektonic communities associated with these live bottom areas.

There is a possibility, therefore, that this investigation is limited by unrecognized latitudinal differences in the characteristics of live bottoms off North Carolina. The shelf waters off North Carolina have three main hydrographically distinct latitudinal divisions (Cape Hatteras north to the Virginia border, Raleigh Bay, and Onslow Bay), and these divisions may have different live bottom communities.

In addition, the characteristics of live bottoms near the shoals which extend from the three capes (Capes Hatteras, Lookout, and Fear) might be distinct from those farther removed from the capes because of differences in hydrography and base rock formation.

Finally, the changes in flora and fauna which occur with depth are probably abrupt, as the live bottom areas are patchily distributed in Raleigh Bay and and Onslow Bay. Consequently, study of one live bottom area at each depth range may not accurately represent abundance and distribution patterns of live bottom organisms in these areas.

Time Sampled:

For the North Carolina portion of the project, which began midway through the contract, sampling was done only during the summer. If only one season can be sampled, late summer is probably the best because diversity of the basically subtropical system is often highest in the warmest months (Peckol 1980, Schneider 1976). The main limitation imposed by the single sampling is the inability to analyze seasonal changes such as the appearance and disappearance of many fish, sessile invertebrates and algae. In addition, a single sampling effort may distort the impression of the presence and abundance of fish because presence and capture at any one site will depend on local meteorological or hydrographic conditions which frequently change over a short time period (days).

Gear Employed:

A wide variety of sampling gear was employed to collect both qualitative and quantitative samples. Due to technological constraints the quantitative information obtained is of severely limited quality when compared to samples taken in terrestrial and shallow aquatic environments. In addition, live bottom areas are, by definition, areas of hard rock substrates where it is often extremely difficult to use collecting gear (e.g., grabs, box corers, and trawls) that can be used very successfully for quantitative sampling of soft bottom areas. Adequate characterization of community structure associated with physically heterogeneous substrates is extremely difficult even in intertidal marine systems and is nearly impossible when sampling must be done from a ship. Samples taken by divers more nearly meet the requirements for quantitative descriptions, but even these are limited by the extreme variation of physical relief on live bottoms which creates numerous microhabitats with distinctive fauna.

Within the limits of current technology, the combination of gear employed provided for a good qualitative description of the areas. This description represents an advance in our understanding of the biology of these systems.

CHAPTER 2

SAMPLING APPROACH AND METHODS

LOCATION OF STUDY AREAS

Based on a review of previous investigations and given the limitation of the depths to be sampled (19 - 100 m), the locations of three study areas were selected (Figure 2.1). At the inner shelf and middle shelf stations, exact location was done by divers whose sampling effort preceded all other sampling. To define the exact location of the deep water station, extensive depth profiling was done once the R/V *Eastward* arrived at the proposed Loran coordinates. Table 2.1 lists for each site the latitude and longitude, maximum and minimum depths, and relief.

Table 2.1 Location, maximum and minimum depths, and relief of the three study sites.

	Latitude	Longitude	Depth (m)	Relief
Inner Shelf (IS04)	35°20.5'N	75°21.6'W	16 - 27	Very high
Middle Shelf (MS04)	33°32.3'N	77°25.0'W	29 - 37	Moderate
Outer Shelf (OS04)	34°51.8'N	75°31.0'W	54 - 98	High

The following paragraphs describe the three study areas and state the reasons for their selection.

Inner Shelf Site:

Located approximately 18.5 km northeast of Cape Hatteras, this rock outcrop was recently identified by Dr. D. Swift of the Marine Geology and Geophysics Laboratory, NOAA, Miami, Florida. Although no biological information was available, sonar records suggested a relict beach rock feature approximately 3.7 km long and 0.9 km wide. The rock outcrop is referred to as "the transverse feature" because of its orientation perpendicular to the normal depth contours of the continental shelf.

Middle Shelf Site:

Located in shoals east of Cape Fear, this is a large area extending 56 km north-south by 8 - 16 km east-west. Based on R/V *Eastward* collections, Dr. R. Searles estimated that dredging there would yield live bottom organisms in more than 50% of the samples. Characterization of the living resources of a representative part of this system would significantly increase our knowledge of the live bottoms off North Carolina.

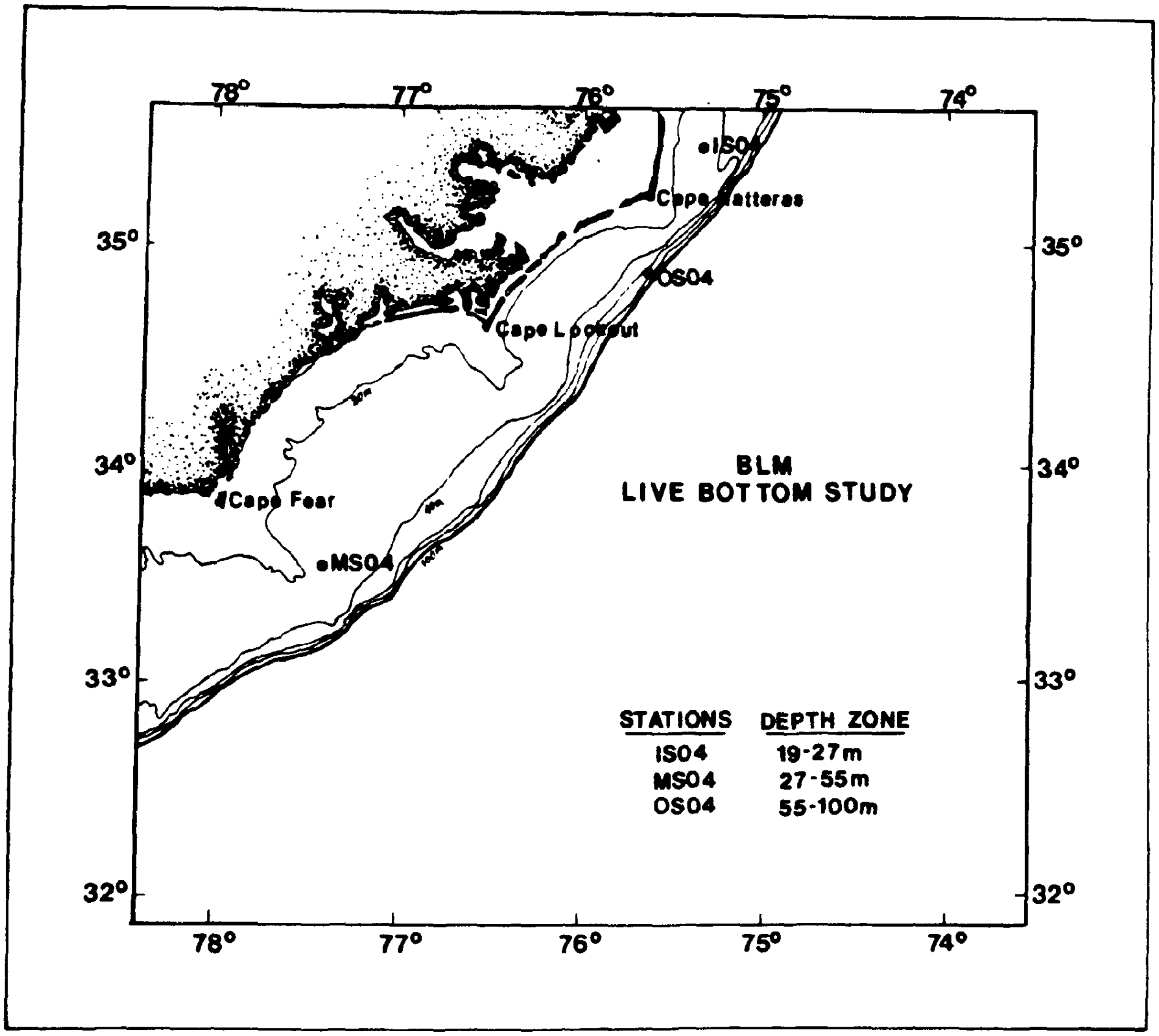

Figure 2.1. Map of North Carolina showing location of study sites.

Outer Shelf Site:

Located approximately 46 km east-southeast of Ocracoke Inlet at the edge of the continental shelf, this area corresponds to Macintyre and Milliman's (1970) Profile A and was selected to represent the northern limit of the Macintyre-Milliman reef structure. The data obtained here are useful in comparison with data for the southern reaches of the same structure obtained by Menzies et al. (1966), SC MRRI (this study), and Avent et al. (1977).

SAMPLING PERIODS

Field sampling efforts were conducted between 15 August and 19 September 1980 as follows:

13-18 August - diving at the inner and middle shelf station;
2-7 September - R/V Eastward cruise for television, still photography, dredge, grab, and hydrographic sampling at all three stations;
15-19 September - R/V Dan Moore cruise for fisheries related sampling (trawling, vertical longline, fish trap, hook and line, and juvenile fish sled) at all three stations.

SAMPLING METHODS

Research Vessels and Navigation:

Two research vessels, R/V Eastward and R/V Dan Moore, and two commercial dive boats were used in field sampling. The R/V Eastward is a 35-m oceanographic research vessel that was owned and operated by Duke University with primary financial support from the National Science Foundation. The R/V Dan Moore is a 26-m fisheries research vessel owned and operated by the State of North Carolina through the North Carolina Division of Marine Fisheries, Morehead City, N.C. Commercial dive boats used for this work were Whipsaw, chartered from Wrightsville Sporting Center, Wrightsville Beach, N.C., and Bluewater, chartered from the Hatteras fishing dock, Hatteras, N.C.

Loran C was used to position all research vessels. A Johnson Laboratory acoustic pinger was released by divers at the inner shelf and middle shelf stations to aid in precise relocation of the sites by the R/V Eastward and R/V Dan Moore. A pinger was released at the outer shelf station during the R/V Eastward cruise to aid relocation by R/V Dan Moore. Attempts to relocate the previously released pingers were unsuccessful; therefore, navigation on research vessels was done solely by Loran C and fathometer.

Hydrographic and Meteorological Methods:

Weather and wave observations were made during each collection effort on every cruise. Data recorded included on board observations of cloud cover, precipitation, wind speed and direction, sea state, air temperature, and barometric pressure. All observations were recorded on appropriate data forms and stored in a clean, dry location at all times. These data as well as other field records are given in Appendix 18, Volume III.

Prior to any dredge or trawl sampling, water samples were collected at 10-m depth intervals by Niskin bottle casts at all three stations. Temperature was measured with a certified bucket thermometer for surface samples and reversing thermometers on the Niskin bottles for samples taken at subsurface depths. Samples for Winkler determination of dissolved oxygen were transferred to 250-ml polyseal glass bottles prior to the collection of any other water samples from the Niskin bottles and chemically preserved with manganous sulphate ($MnSO_4$) and alkaline iodide (KI) according to the method of Strickland and Parsons (1972) for later analysis on board the ship. Salinity samples were collected in 250-ml polyethylene bottles and immediately frozen for subsequent analysis at the laboratory. Freezing of the salinity samples introduced a possibility of erroneous values, because some of the sample bottles were not stored in an upright position. Leakage of the more saline liquid phase of the sample during freezing could account for two very low salinities (20.5°/₀₀ and 21.9°/₀₀) at the outer shelf station. Because of this error in handling, all salinity data were considered suspect and will not be presented in this report.

Within 24 hr of collection time, each set of dissolved oxygen samples was analyzed by the modified Winkler titration procedure described by Strickland and Parsons (1972).

At all three sites during the R/V Eastward cruise, a Martek Model XMS transmissometer was used at 10-m depth intervals to measure percent light transmission. These measurements were made immediately following the Niskin bottle cast and prior to any dredge or trawl sampling to avoid particulate contamination of the water column.

Light penetration was measured with a Secchi disk at each sampling site during the R/V Eastward cruise and also at the inner shelf and middle shelf sites during the dive cruises. Secchi disk lowerings were made as close as possible to local apparent noon.

Physical Habitat Characterization:

The physical characterization of the live bottom habitat was initially accomplished with the aid of an echo-sounding fathometer. Fathometer tracings and associated Loran C coordinates were recorded while the vessel traveled on a grid pattern over each study area. The fathometer transects aided in the evaluation of the relief and geographic extent of the live bottom area.

The Hydro Products Model TC-125 SDA, a low light level, silicon diode array, television camera, was used for the underwater television reconnaissance and transect sampling. The camera was connected by a Model C-105 cable assembly to a Model TP-110 camera power supply and to a standard 19-in. black and white monitor. A Model LT-7 (Hydro Products) underwater light assembly with a Model LB-250 gas discharge lamp ballast was used in conjunction with the camera.

The television camera and associated cable, mounted in a frame, were fastened to the vessel's hydrowire with plastic ties and lowered to the bottom using the hydrowinch aboard the research vessel. Television reconnaissance was recorded by an RCA video cassette recorder beginning at the point where live bottom was identified, that is, where rock or live bottom organisms appeared on the television monitor. The vessel drifted across the study area recording information as long as rock or live bottom organisms were present. If six consecutive minutes of sand bottom occurred within a transect, the recorder was turned off until live bottom was again encountered. At 2-min intervals throughout the entire television reconnaissance, notes were made of time, Loran coordinates, estimates of percent cover of live bottom, and additional comments on the mechanics of the operation (such as the quality of the television picture) and the live bottom itself (presence of ledges, general mention of flora and fauna viewed). From the videotape footage recorded at MS04 and OS04, three 20-min transects were selected for laboratory analysis. Poor bottom visibility and high relief precluded TV reconnaissance at IS04.

A Benthos Model 371 Edgerton camera equipped with a Model 381 flash unit was used for the 35-mm still pictures to be taken at 1-m and 3-m distances off the bottom. However, camera malfunction precluded still-picture transects at any of the sites.

During diving operations at the inner and middle shelf sites (IS04 and MS04) direct observations and ground-truth and close-up photographs of rock relief were made by divers. A Cerame-Vivas dredge was used to sample the rock at each of the study areas.

Biological Community Characterization:

A multi-gear strategy was employed for complete sampling of the demersal fish community, ranging from small juvenile fish to large adult predators. Sampling gear included a trawl, rods and reels, traps, longlines and a benthic juvenile fish sled.

The trawl, a 40/54 highfly net (Hillier 1974), has a small liner sewn into the bag of the trawl to capture juvenile and small fishes. Each station was to be trawled six times, three during the day and three at night. Distance covered by each trawling effort was approximately 1 km at a vessel speed of 3.5 kn.

Three gear types, rod and reel, longline, and trap, were utilized for baited fishing; squid and cut fish served as bait for all gear. Each gear was deployed twice at each station, once during dawn and again during dusk hours. Rod and reel fishing gear was similar to that used on recreational headboats (Huntsman 1976). Bottom rigs were made with three hooks, either 6/0 circle hooks or 4/0 or 8/0 J-hooks, spaced 30.5 cm (1 ft) apart to capture the large, predatory species of the snapper/grouper community. Four vertical longlines (Olsen et al. 1974) were fished during each sampling period at each station to catch additional predatory species. Hooks used were the same as those described above; however, they were spaced 61 cm (2 ft) apart. The fish traps were similar to Antillean "S" traps (Powles and Barans 1980) with outside dimensions of 0.30-m height, 1.22-m width and 1.22 m-length. Four traps were fished simultaneously with two traps on the bottom and two traps suspended 4.6 m off the bottom.

Two juvenile fish sled tows were to be made during the night at each station. This gear was lost during first deployment and no samples were collected.

Fish collected with trawl, trap, rod and reel, and longline gear were sorted to species aboard the R/V _Dan Moore_. Total weight (in kilograms) for each species was recorded and individual fork lengths were measured to the nearest centimetre. When large numbers of a single species were caught, a total weight was recorded and a subsample (approximately 25%) was weighed and measured.

When specimens of the seven priority species were caught, stomachs were taken and additional life history information was recorded. The seven priority species are black sea bass, _Centropristis striata_; red snapper, _Lutjanus campechanus_; snowy grouper, _Epinephelus niveatus_; scamp, _Mycteroperca phenax_; gag, _Mycteroperca microlepsis_; vermilion snapper, _Rhomboplites aurorubens_; and red porgy, _Pagrus pagrus_. Information recorded on these fish included weight, sex (when determinable), and standard, fork and total lengths in millimetres.

Stomachs containing food were removed, placed in a cloth bag with station identification tag, and preserved in 10% formalin; stomachs without visible food items were counted and discarded. Stomachs and life history information were also collected from the following dominant non-priority species: white grunt, Haemulon plumieri; tomtate grunt, Haemulon aurolineatum; and southern porgy, Stenotomus aculeatus.

A voucher collection of fishes was maintained by freezing a representative individual(s) of each species. The frozen vouchers were returned to the laboratory, verified, photographed, fixed in 10% formalin and later transferred to 50% propanol.

Invertebrates and algae sampled by trawl were sorted to major groups and weighed (kg). Samples were then relaxed in a saturated solution of Epsom salts prior to preservation in a 5% formalin-seawater solution buffered with hexamethylenamine. To preserve color and texture, sponges were frozen rather than fixed with formalin.

In the high relief areas at IS04 and MS04, divers swam observation transects to document fish species which might be missed using standard trawling methods. At MS04 two divers swam a 15-min transect along the edge of the ledge drop-off, covering a distance of 46 m. Due to reduced visibility (< 1 m) at IS04 which restricted diver movements, a 15-min circular transect (360°) was completed in an area near the edge of a ledge drop-off. In addition to the observation transects, direct capture techniques (spearfishing and poison stations) were utilized by divers at IS04 and MS04 to collect both priority fish species and those species which could have avoided traps and trawls.

Five replicate airlift suction samples (surface area of 0.1 m^2 per sample) were taken at IS04 and MS04. A metal disc, with five equally spaced points marked along its circumference, was positioned by divers in the center of the area sampled. A 3-m line tied to the center of the disc was placed consecutively in the five directions marked on the disc. A square grid of nine 0.1-m^2 quadrats had been located at the end of each of the five lines. One of the nine possible quadrats was preselected by a table of random numbers to be sampled. The organisms within the quadrats were scraped from the rock surfaces and sucked into the sampler. Aboard the dive vessel, the samples were numbered, relaxed for 2 hr in Epsom salts ($MgSO_4$), and preserved in a 5% formalin-seawater solution buffered with hexamethylenamine. The samples were returned to the laboratory for analysis. At OS04 five 0.1-m^2 samples were collected using a Smith-McIntyre grab. The grab was lowered in the live bottom area (as indicated on the fathometer tracing) for a collection. Following sieving through 1-mm mesh aboard the vessel, the samples were relaxed with Epsom salts, stained with rose bengal, and preserved in a buffered 10% formalin-seawater solution.

Qualitative assessments of the epibenthic communities were made from samples collected at all three study areas with two replicate Cerame-Vivas benthic rock dredge collections (dredge mouth 90 x 25 cm) and through analysis of the invertebrates and algae collected in six trawl tows. Tow distance at each study area was approximately 0.15 and 1 km for dredge and trawl samples, respectively. All samples collected by the dredge and trawl were relaxed for 2 hr in Epsom salts and preserved aboard the vessel. Certain specimens (e.g., sponges) collected in the dredge and trawl tows were photographed in color and described thoroughly prior to preservation as an aid in the identification process. The epibenthic collections and rock samples were returned to the laboratory for analysis.

A representative of every invertebrate and algal species identified was preserved and placed in a voucher collection.

CHAPTER 3

HYDROGRAPHY AND WEATHER OBSERVATIONS

INTRODUCTION

There is a large body of information available on the hydrography of the continental shelf off North Carolina (Stefansson and Atkinson 1967, Curtin 1979). This investigation included hydrographic procedures to determine whether conditions at the time of sampling were within the range of conditions previously documented for each sampling location. Therefore, at each study site our sampling plan included measuring temperature, salinity, dissolved oxygen, and light transmission at 10-m depth intervals. Secchi disk measurements of light penetration also were made at each station at local noon. In addition to this water column sampling, weather observations were recorded at the time of each collection effort.

LABORATORY METHODS

From raw temperature data, corrected temperatures at sampled depths were calculated using January 1981 thermometer calibration data.

All weather and wave observation forms were sent to SC MRRI for reduction and tabulation as required for data interpretation and synthesis.

RESULTS

Reduced data on temperature and dissolved oxygen are presented in Figure 3.1 and Appendix 29. Light transmission data are given in Table 3.1 and Figure 3.1.

DISCUSSION

Temperature data collected at the inner shelf station (IS04) at Cape Hatteras are comparable to the values found for Virginia water as described in Figure 5.4-7 by Curtin (1979), whose results were based on all of the bottle cast data on file at NODC in 1977.

At the middle shelf station (MS04), the mid-depth water fell within the temperature definition of Virginia water, and water at the greatest depth sampled (20 m) was within the temperature domains of Carolina water and Gulf Stream water (Curtin 1979).

Temperature data from the upper 20 m at the outer shelf station (OS04) fall among historical temperature values for this location and season (Figure 5.3-50, Curtin 1979), but outside the domain described in Figure 5.4-7 of Curtin (1979).

Dissolved oxygen values obtained at all three stations were within the range of values reported by Curtin (1979), based on data on file at NODC in 1977, and Stefansson and Atkinson (1967) for the summer in the same locations.

Light transmission ranged from 72% to 94%; Secchi depths ranged from 19.5 m to 22.0 m and were within the range of previous observations for these sites (Curtin 1979).

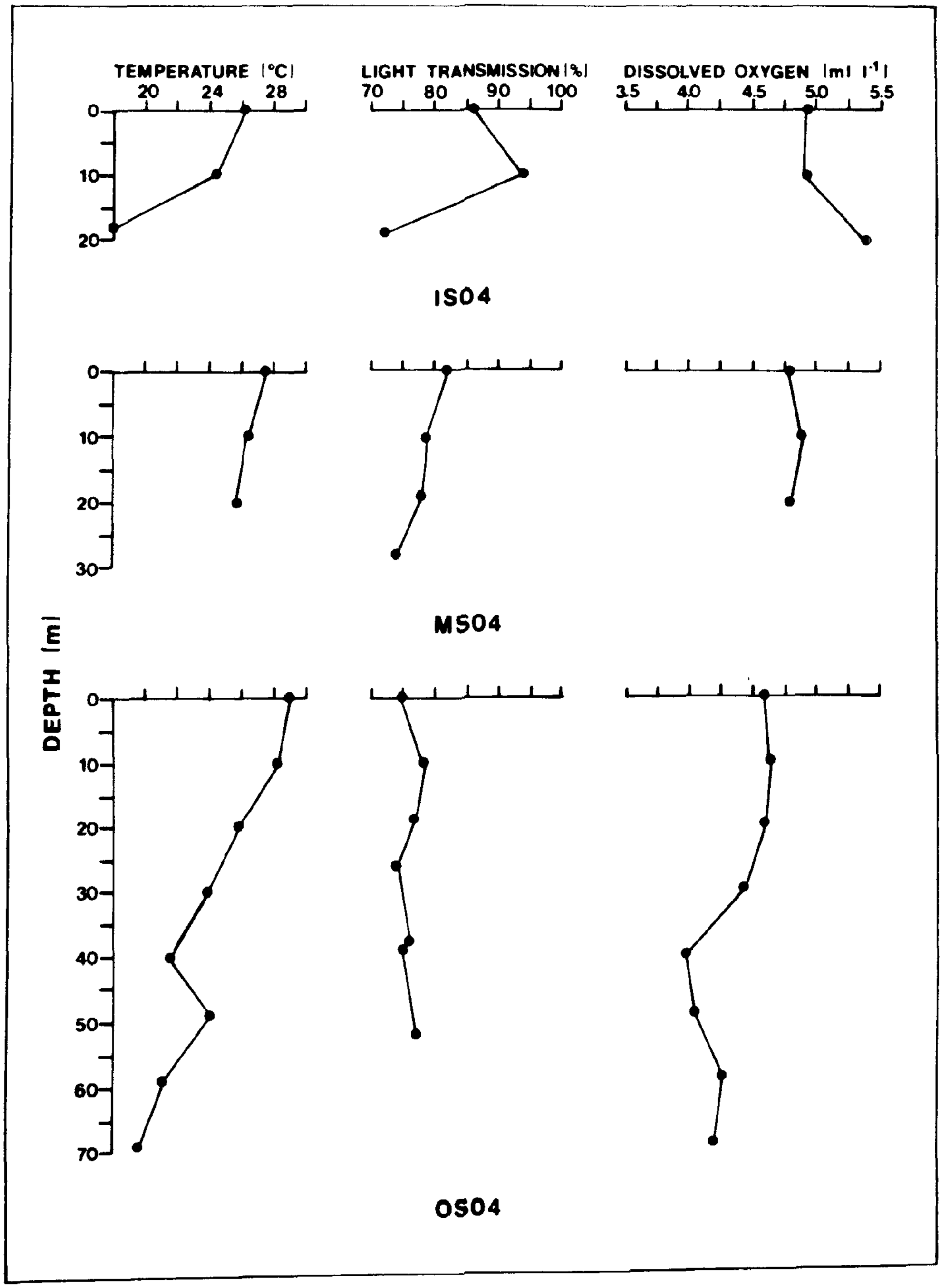

Figure 3.1. Vertical profiles of temperature (°C), dissolved oxygen (ml l^{-1}), and light transmission (%) at three stations in summer 1980.

Table 3.1 Percent light transmission by depth at three stations off North Carolina for summer 1980.

	Accepted Depth (m)	Percent Light Transmission
Station IS04	0	86
	10	94
	19	72
Station MS04	0	82
	10	79
	19	78
	28	74
Station OS04	0	75
	10	78
	19	77
	26	74
	38	76
	39	75
	52	77

The major limitation of the hydrographic and meteorological data is that the data represent conditions at only one point in time. The temperature data were further limited by the lack of recent calibration data for the thermometers used for the 10-m and 20-m depths at IS04. Temperatures were read to the nearest 0.05°C instead of the conventional 0.02°C. In addition, there were discrepancies of > 0.1°C between the sequential readings of thermometers used at the following depths: 10 m at IS04; 10 and 20 m at MS04; and 10, 20, 40, and 60 m at OS04.

IMPACT/ENHANCEMENT

The impact of hydrocarbon exploration on the hydrography of South Atlantic continental shelf water is expected to be primarily a decrease in water clarity (increase in turbidity) in the vicinity of drilling platforms due to release of produced water containing a finite concentration of suspended solids as well as measurable concentrations of dissolved hydrocarbons, organics, and metals. This impact is expected to be limited to the close proximity of the platform.

No enhancement of water quality and hydrography is expected to occur as a result of hydrocarbon exploration.

CONCLUSIONS

Temperature, dissolved oxygen, and light penetration values at the three sampling sites fell within ranges observed previously at these locations.

CHAPTER 4

PHYSICAL CHARACTERIZATION OF STUDY AREAS

INTRODUCTION

Prerequisite to describing the abundance and distribution of algal, invertebrate, and fish species on live bottom areas of the continental shelf off North Carolina is an assessment of the hard bottom habitat where these organisms are found. Physical characterization of the inner, middle, and outer shelf study areas included the determination of relief, geographic extent, and percent sediment cover at the three study areas. Limitations to the accurate assessment of the three sites included reduced water clarity, which restricted diver observations and accuracy of television reconnaissance, and the relief of the live bottom area, which prevented the use of equipment in some cases.

Due to a low rate of sedimentation, rock outcropping is frequent in Onslow Bay (Cleary and Pilkey 1968); whereas the heavy sediment load characteristic of Raleigh Bay has reduced the amount of emergent rock there (Newton et al. 1971). Along the shelf break off North Carolina there is a noticeable reduction of sediment accumulation because of the movements and proximity of the Gulf Stream (Menzies et al. 1966, Macintyre and Milliman 1970). From Cape Fear to Cape Canaveral there is an absence of pronounced physiographic features along the shelf break due to sediment accumulation (Macintyre and Milliman 1970).

A variety of live bottom types occur on the continental shelf adjacent to the Carolinas. Low relief coral "reefs" are widespread in Onslow Bay (Huntsman and Macintyre 1971) where winter bottom temperatures as low as 10.6°C have been recorded. These areas offer suitable conditions for the establishment of hermatypic head corals, *Solenastrea hyades* and *Siderastrea siderea* (Macintyre and Pilkey 1969). Other hard bottom types include the numerous late Pleistocene rock outcroppings of relict shallow water assemblages (Mixon and Pilkey 1976) and a relict algal ridge system extending along the shelf break that flourished in shallow water about 20,000 years ago (Menzies et al. 1966).

Included in this chapter is a physical description of the three study areas, IS04, MS04, and OS04, compiled from data taken on the summer 1980 sampling effort.

METHODS

Fathometer echograms and videotapes were brought into the laboratory for processing. The Loran coordinates recorded during the fathometer transects were converted to latitude and longitude readings and plotted along with the depth at each set of coordinates to determine depth profiles, relief, and geographic extent at each study area. Three 20-min videotapes were extracted from the footage recorded at MS04 and OS04. Analysis of the 20-min segments consisted of recording presence or absence of live bottom, sand, and rock ledges within each 10-sec interval comprising the 20-min segments. The portion of the videotape occupying the middle third of the monitor was used in this analysis to determine geographic extent, relief, and percent sediment cover of each study area.

RESULTS

Inner Shelf Station:

Diver Observations - The location of the diver sampling area within IS04 was near the edge of a ledge, but the drop-off was not pronounced (< 3 m). Poor lateral visibility (< 1 m) prevented an accurate assessment of the area and precluded photographic documentation. Fine silt covered most of the rock surface and was suspended in the water column. No appreciable current was observed during diving operations, but two distinct thermoclines were encountered in the water column. (Depth of the thermoclines was not determined.)

Fathometer Transects - Shown in Figure 4.1 is the depth profile for IS04 determined from the fathometer transect. The study area is approximately 3.2 km^2 with a depth range of 16 - 27 m. Fathometer tracings revealed an area of extremely high relief characterized by large broken ledges and isolated boulders greater than 5 m in height. There was no distinct orientation of the ledges; instead, the jagged relief indicated by sonar tracking suggested that trawling over this area would be impossible without the loss of gear.

Middle Shelf Station:

Diver Observations - According to the fathometer tracks, the rock outcropping at MS04 is a fairly extensive area of jagged, uneven bottom with moderate relief. In southerly portions of the area the ledge became more table-like in aspect and finally dropped off vertically 3 m at the dive site. Closer assessment revealed that the rock outcropping did not have an abrupt, steep edge, but consisted of small broken rock pieces (approximately 25 cm diameter) dissected by large channels. The topography of the reef edge was extremely rugged and complex. Photographs taken by divers at MS04 are shown in Figures 4.2 and 4.3.

There was little accumulation of sediment on the rock outcrop and lateral visibility was excellent (> 15 m). Surface and bottom currents were extremely variable throughout the sampling period. In spite of strong currents, a pronounced thermocline was evidenced about 12 m off the bottom.

Fathometer Transects - The geographic extent of the study area is approximately 10 km^2 with a depth range of 29 - 37 m (Figure 4.4). Sonar tracking indicated that MS04 is an area of moderate relief, lacking the large jagged boulders evidenced at IS04. The northerly portion of the study area appeared to be a field of broken rock ledges with generally an east-west orientation. In the southerly portions of the site the rock outcrop became fairly level with fewer abrupt ledges.

Television Reconnaissance and Transects - Shown in Figure 4.5 are the cruise tracks of the television reconnaissance and three 20-min transects completed at MS04. Occurrence of ledges is indicated for the analyzed portion of the transect only. Both the unanalyzed portion of the reconnaissance and the three replicate transects (Figure 4.6) indicated an extensive live bottom area (96%) with low to moderate relief (10% ledges). As suggested by diver observation, MS04 has little sediment accumulation and the exposed rock

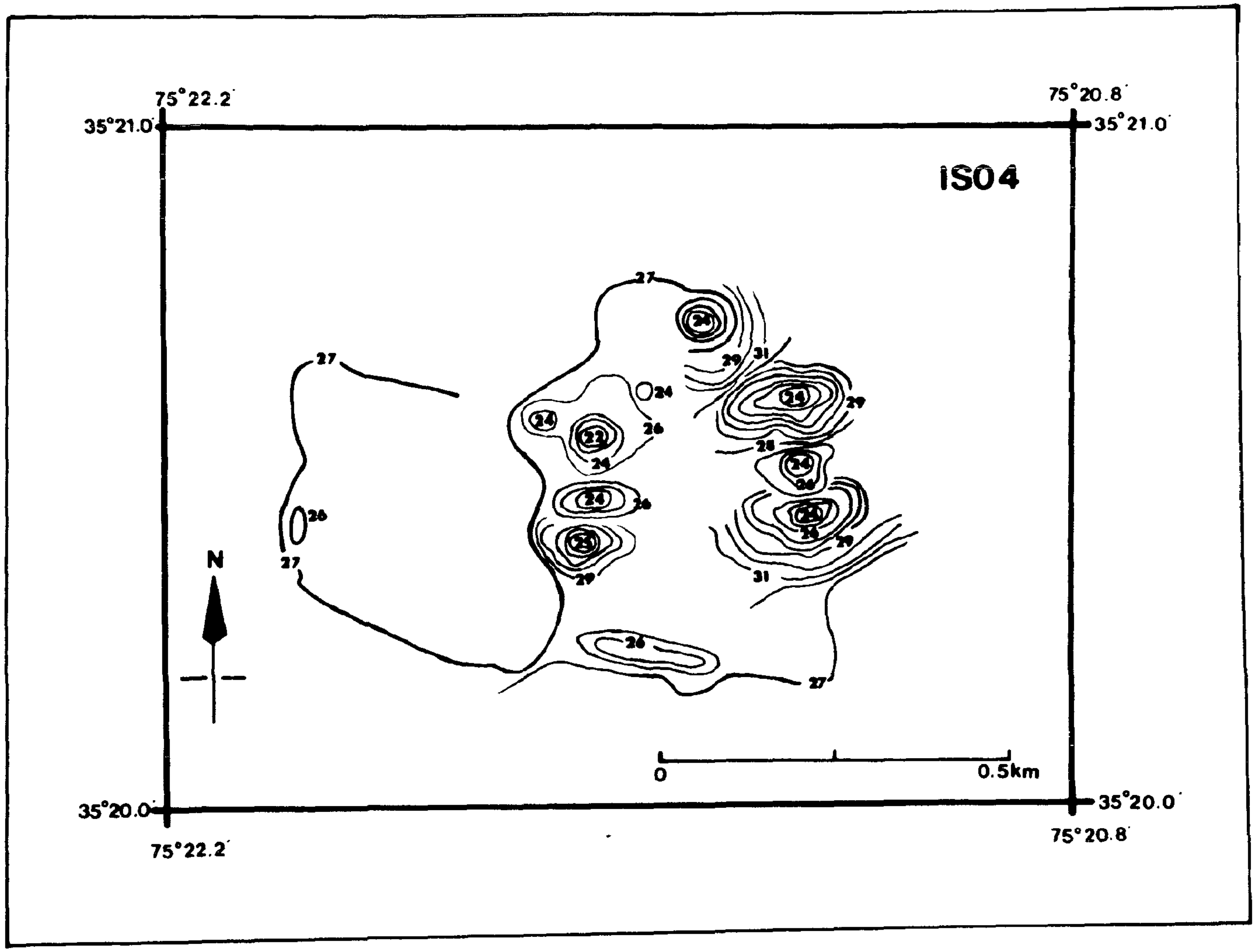

Figure 4.1. Depth profile for IS04 determined from fathometer transect.

Figure 4.2. Ground-truth photograph taken at MS04 in August 1980 showing moderate relief. The white grunt (Haemulon plumieri) pictured are approximately 30 cm long.

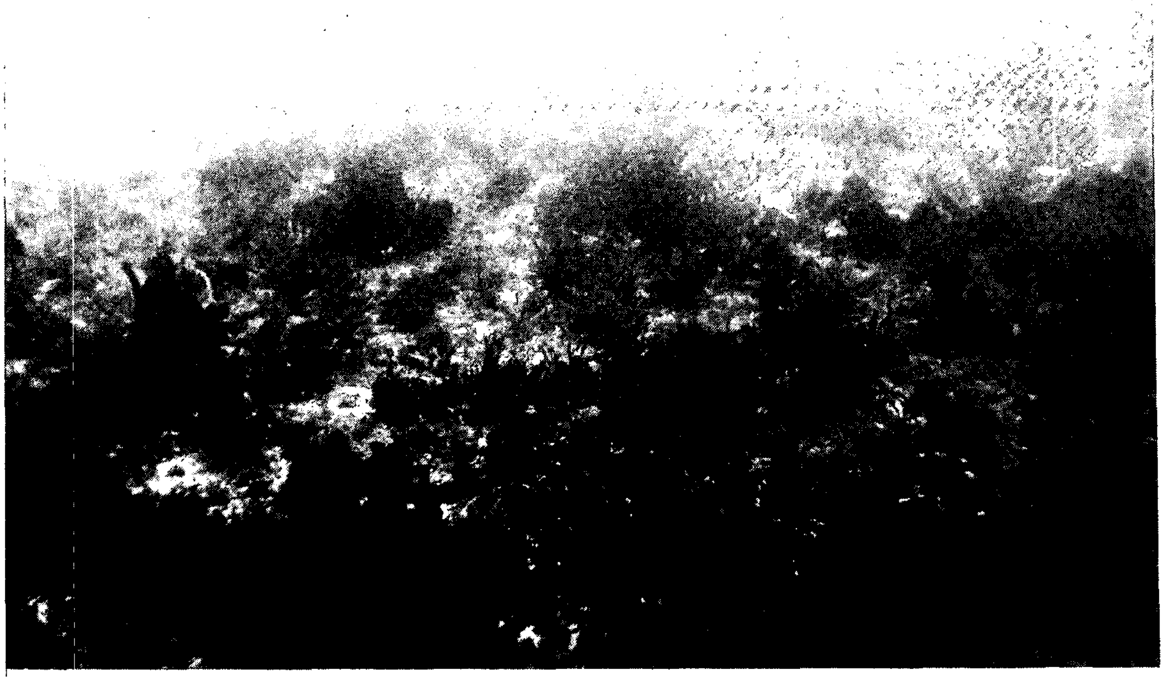

Figure 4.3. Ground-truth photograph taken at MS04 in August 1980 showing low relief. The alga Dictyopteris hoytii in foreground is approximately 40 cm high.

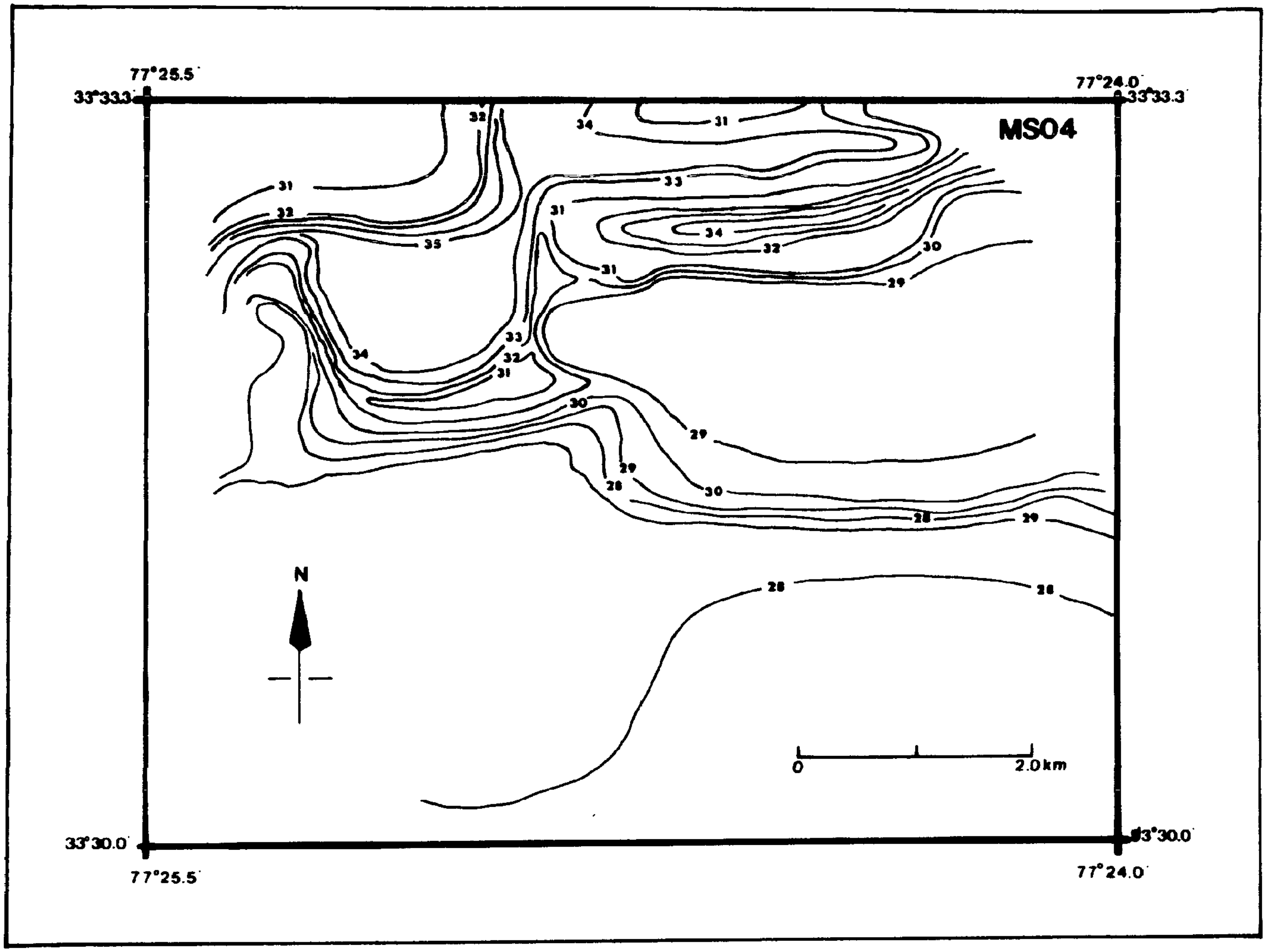

Figure 4.4. Depth profile for MS04 determined from fathometer transect.

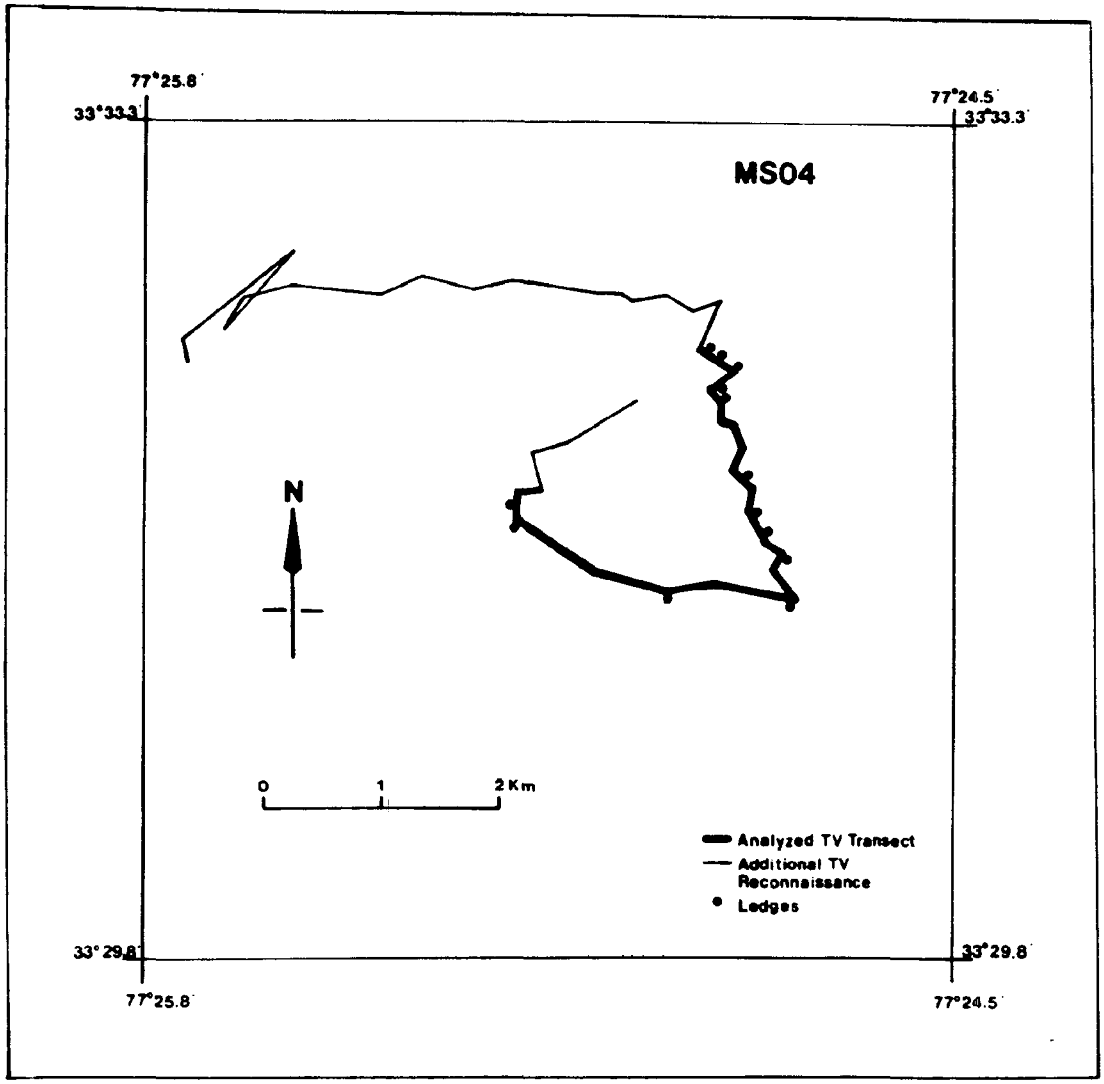

Figure 4.5. Cruise tracks of unanalyzed television reconnaissance and analyzed transect completed at MS04. Ledges are indicated for analyzed portion only.

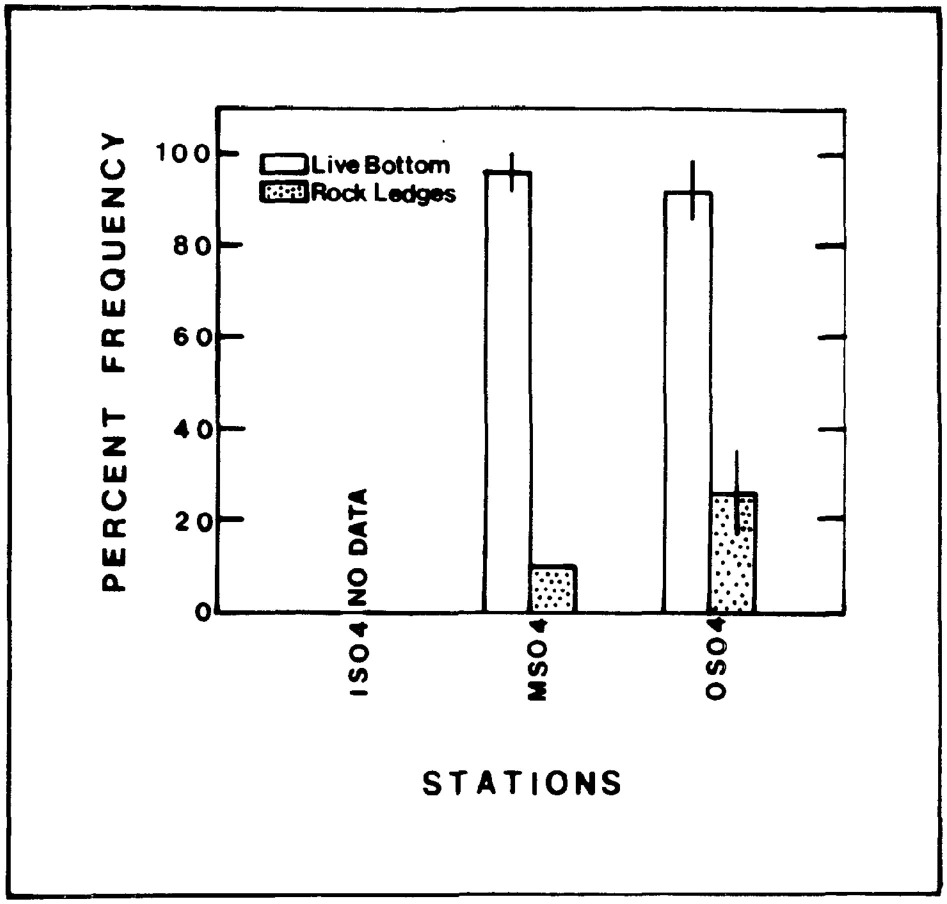

Figure 4.6. Percent live bottom and rock ledges (shown as mean percent frequency $\pm$ 1 SE) determined from three television transects at each study area.

outcroppings are available to support a lush growth of live bottom organisms.

Outer Shelf Station:

Fathometer Transects - Although sonar tracking indicated that the outer shelf station is very extensive, an area 5 km^2, ranging in depth from 54 - 98 m, was delineated for extensive live bottom study (Figure 4.7). The fathometer transect indicated this area is a continuous reef structure with a northeast-southwest orientation and gradual rather than abrupt changes in depth along the north-south axis. Although OS04 did not appear to have the type of ledges occurring at both IS04 and MS04, the depth range at this station was much greater than at either the inner or middle shelf site.

Television Reconnaissance and Transects - Shown in Figure 4.8 are the cruise tracks of the television reconnaissance and three 20-min transects completed at OS04. TV analysis indicated that this site, like MS04, contains extensive live bottom areas (Figure 4.6). In contrast to the low profile indicated by sonar tracking, the TV analysis suggests that OS04 has a higher percentage of boulders and ledges (26%) than MS04. Many of the ledges seen along the television transects were not distinguished by fathometer. OS04 has little sediment accumulation on the rock outcroppings; however, there was a great amount of material in the water column (suspended sediment) during television reconnaissance and transect work.

DISCUSSION

Results of this study indicate that IS04, MS04, and OS04 differ greatly in geographic extent, percent sediment cover, and level of relief. IS04, which appeared to be an island of emergent rock rising rather abruptly from the surrounding sand (Figure 4.1), was very limited in geographic extent. Both MS04 and OS04 were more extensive (Figures 4.4 and 4.7); in fact, OS04 is part of a continuous reef structure extending to Florida (Macintyre and Milliman 1970). A reef structure comparable to OS04 has been described in the northeastern Gulf of Mexico (Ludwick and Walton 1957) and these workers indicate that while the reef itself was not growing, a diverse community of organisms utilized the area as substrate.

As suggested by others (Cleary and Pilkey 1968), there is low sediment accumulation in Onslow Bay. MS04, located in the southern portion of Onslow Bay, had very little suspended material in the water column and negligible sedimentation covering the live bottom area (Figure 4.6). In contrast, IS04, located north of Cape Hatteras, had a large sediment load, reflected by reduced water clarity and heavy accumulation on the rock surface. OS04 was characterized by low sediment accumulation on the emergent rock, an effect of the Gulf Stream in this area (Macintyre and Milliman 1970). The amount of sedimentation in an area is an important factor determining abundance and distribution of invertebrate and algal species characteristic of live bottom areas. Menzies et al. (1966) found that the living fauna associated with a submerged reef off North Carolina were distributed according to zones of differing sedimentation and that certain attached epifaunal species (e.g., *Plicatula gibbosa*, *Barbatia candida*, *Chama congregata*, and *Arca zebra*) were found specifically in areas of slow deposition. Loya (1976) found that sedimentation had an important effect on community structure in Puerto Rican

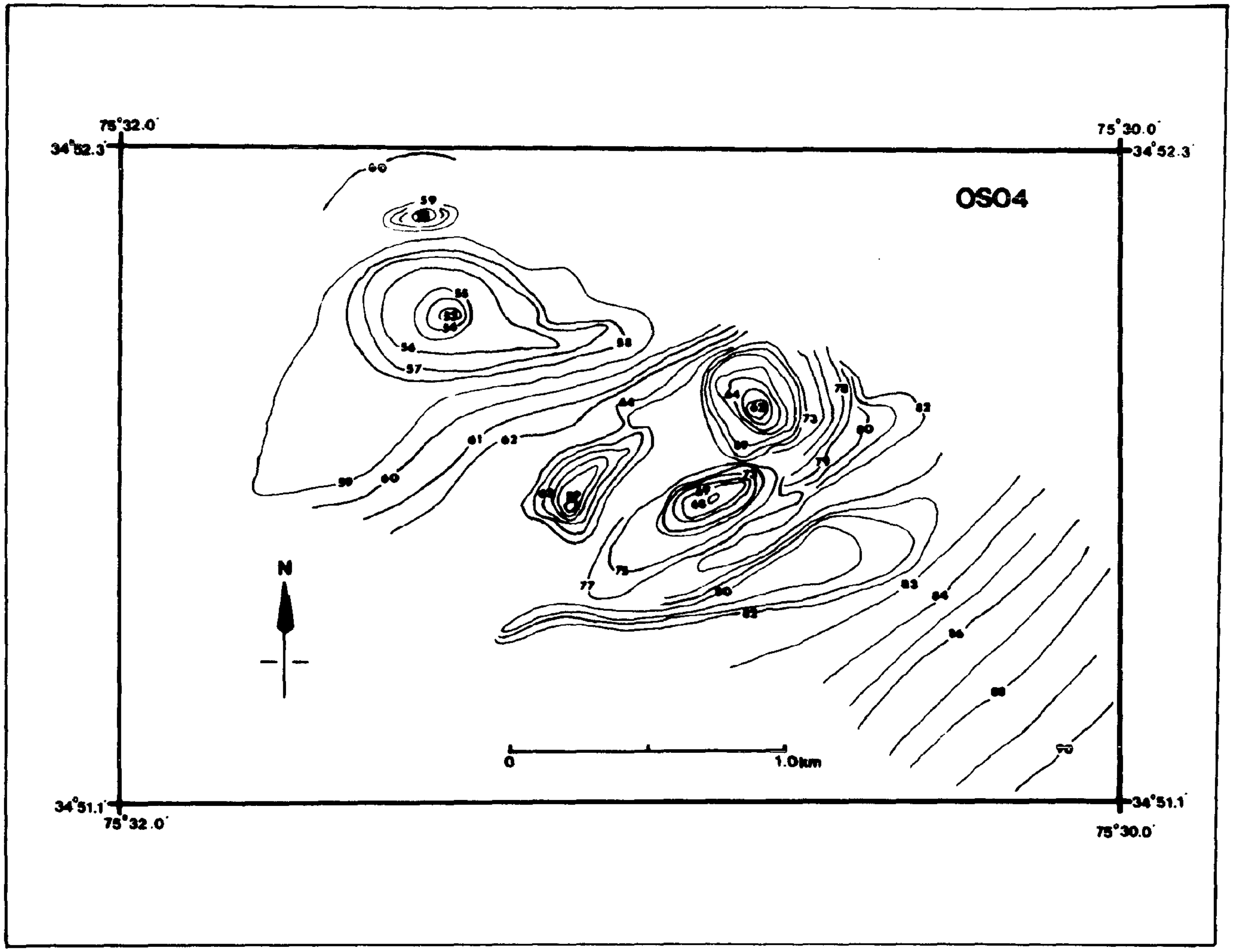

Figure 4.7 Depth profile for OS04 determined from fathometer transect.

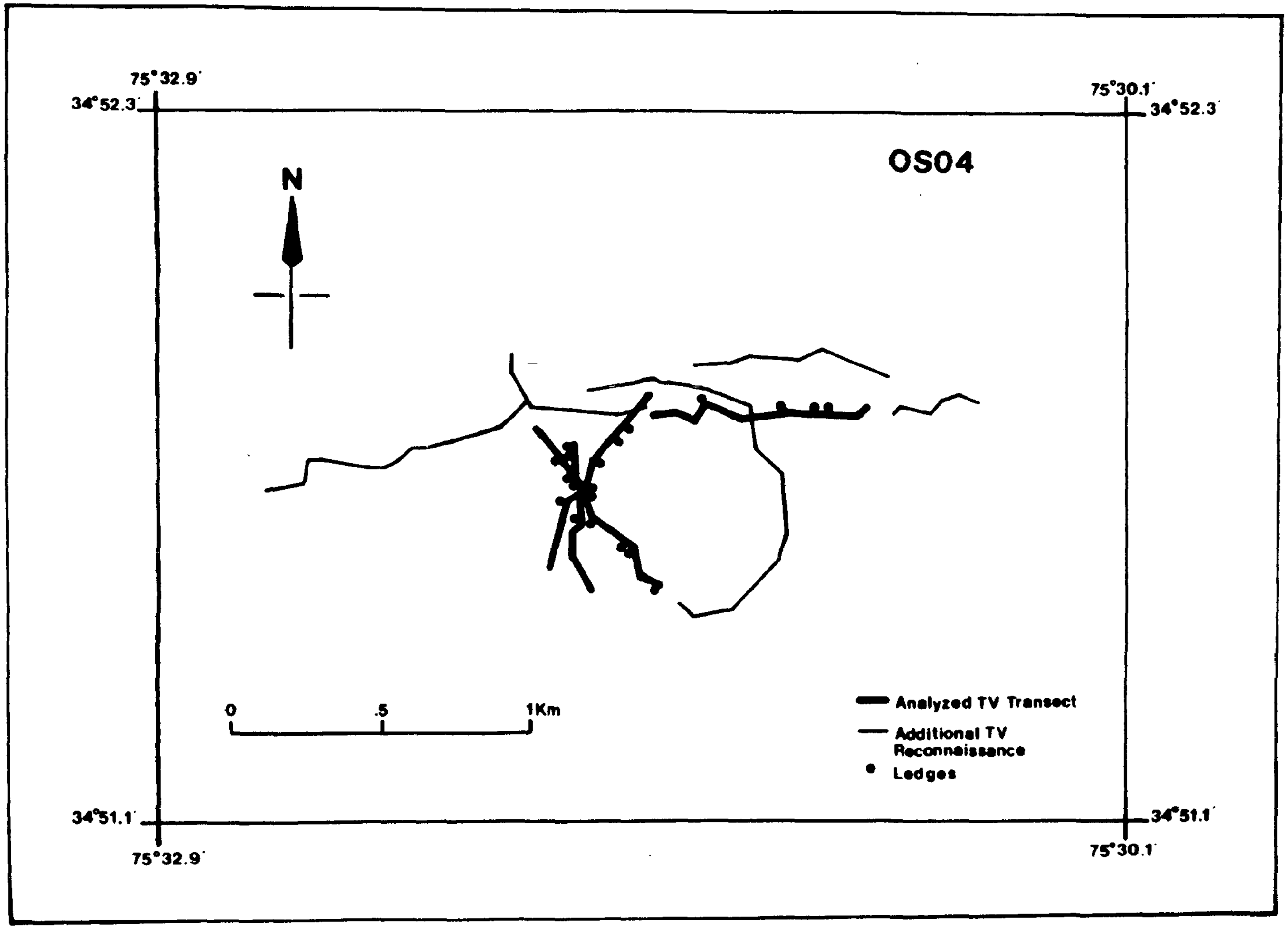

Figure 4.8. Cruise tracks of unanalyzed television reconnaissance and analyzed transect completed at OS04. Ledges are indicated for analyzed portion only.

coral reefs. Heavy sedimentation will reduce the substrata available for attachment by algae in addition to reducing available light for growth (Cheney and Dyer 1974, Kapraun 1974, Sears and Wilce 1975, Schneider 1976, Peckol 1980).

Results from this study indicate that while MS04 is an area of moderate relief, both IS04 and OS04 are characterized by large boulders and jagged ledges. Macintyre and Milliman (1970) felt that the large ridges and troughs characteristic of the submerged reef along the shelf break were due to earlier differential erosion by the Gulf Stream. All three study areas have adequate relief to support live bottom communities. The importance of the emergent rock outcroppings and reef structures to fish productivity is apparent: the existence of these structures provides refuge for the fish while the abundance of attached invertebrates and algae reflects the large standing crop available as a food resource.

IMPACT/ENHANCEMENT

The impact of hydrocarbon exploration activities on the physical characteristics of live bottoms, if permitted, is expected to be a function of the conditions prevailing at a specific site. Accumulation of drilling muds and cuttings in the immediate vicinity of drilling platforms is expected to change the nature of the bottom (at least temporarily) such that it will more nearly resemble a soft bottom habitat. In shallow areas (such as IS04) storm wave action and strong wind driven currents probably will cause a much wider dispersal of material and only slight alteration of the physical relief. At deeper locations (MS04 and OS04) drilling muds and cuttings probably will remain in the vicinity of the drilling activities, converting the area to a soft bottom habitat. This may be particularly true in Onslow Bay (MS04 and similar live bottoms) which experiences almost no natural sedimentation and has low to moderate relief. OS04 probably experiences periodic strong currents (as the Gulf Stream meanders on and off the edge of the shelf) which might result in periodic dispersal of accumulated loose muds and cuttings.

Drilling platforms will provide increased surface area of hard substrate available for live bottom community development. The effects of this enhancement, however, would occur only in local areas near platforms. Whether this enhancement will balance the impact of drilling deposition would depend on the respective areas affected at each site.

CONCLUSIONS

The type of live bottom community that can develop is determined in large part by the physical characteristics (relief and number and size of rocks and ledges) of the base rock formation. Scuba and television transects show that the margins of ledges provide the best habitat and support the greatest density of organisms including fishes; and within a site, the greater the relief of the area and the more numerous the ledges and crevices, the greater the biomass and diversity of organisms.

Due to the great differences in relief, sedimentation rate and type, and geographic extent among the three study sites, it is impossible to say, based on only three areas, which if any differences in physical characteristics result from differences of depth. However, based on previous investigations we expect that greater physical relief occurs at rock outcrops near the shoals which extend seaward from Cape Hatteras, Cape Lookout, and Cape Fear along the edge of the continental shelf. Much lower relief is encountered in the middle shelf, mid-bay live bottoms off the coast of North Carolina. There are few live bottom areas north of Cape Hatteras and in Raleigh Bay (R.B. Searles, pers. comm., Duke University, Durham, NC, 1980), but extensive outcroppings occur throughout Onslow Bay.

In summary, IS04, located just north of Cape Hatteras Shoals, is a relatively small area of high relief with some boulders 5-m high. There is no apparent orientation of the rocks or ledges. Two distinct changes in temperature were noted in the overlying waters and a large amount of sediment covered the rocks and was suspended in the water column.

MS04, located north of Cape Fear Shoals, is a large area with moderate relief (oriented east-west) in the north and with fewer ledges in the south. A lush growth of organisms was observed with little sediment either on the bottom or in the water column.

OS04, located at the edge of the continental shelf in Raleigh Bay, is part of a large reef system which extends from Cape Hatteras to Florida. Numerous moderate size boulders and ledges were observed with the television camera, while the fathometer indicated a very steep, but not ledge-like, profile. Little sediment occurred on the rocks, although the water was moderately turbid near the bottom (as observed by television camera).

CHAPTER 5

BENTHIC COMMUNITY

INTRODUCTION

Knowledge of the abundance and distribution of algal and invertebrate species associated with the hard bottom habitats on the Carolina shelf is relatively incomplete. Previous studies (Hoyt 1920, Pearse and Williams 1951, Schneider 1976) indicated that affinities existed between the offshore algae and the Caribbean flora and that North Carolina was the northern distributional limit of many of these species. Other studies concerned with the continental shelf habitats off North Carolina (Cerame-Vivas and Gray 1966, Grassle 1967, Day et al. 1971) and biogeographical analyses of the western North Atlantic (Parr 1933, Briggs 1974, van den Hoek 1975, Searles and Schneider 1980) have indicated that the Carolina shelf is a transitional zone where algal and invertebrate species of both northern and southern affinity can be found. Annual variations in the dominant water masses result in large temperature fluctuations off the coast of North Carolina (Cerame-Vivas and Gray 1966, Peckol 1980) which create a rigorous environment for species of northern or southern affinity (Parr 1933).

The evident importance of these hard bottom assemblages as habitat and food resources for commercially important fish and for invertebrate species necessitates an increased effort to characterize these live bottom communities. One aim of this study is to determine species composition, biomass, and diversity of three live bottom areas occurring on the continental shelf of North Carolina. Further, this study attempts to elucidate floral and faunal affinities among the various live bottom areas and to speculate on potential impact/enhancement effects associated with drilling operations in these areas.

METHODS

Laboratory Analysis:

On the basis of visibility, three 20-min videotape segments were selected from footage recorded at MS04 and OS04. Analysis of the 20-min segments consisted of recording presence or absence of selected invertebrate species and algae within each 10-sec interval comprising the 20-min segments. The high density of many species and conditions of poor visibility made it impossible to make direct counts. The portion of the videotape occurring in the lower third of the middle third (1/9) of the monitor was used in the analysis to insure uniform clarity and similar distance travelled in each 10-sec interval. Due to movement of the camera, the area of live bottom recorded was not constant.

Biological samples collected with suction, grab, dredge and trawl at each station were separated from non-living and inorganic material, sorted to major taxa, preserved in 50% isopropyl alcohol, and identified to the lowest taxonomic level in the time allowed by the contract. A voucher collection composed of every identified taxon was prepared. With the exception of the colonial forms and algae, the number of individuals for each taxon was determined for the suction and grab samples. All taxa collected by dredge and trawl were weighed (wet) to the nearest 0.01 g.

The taxa identified from each sampling gear are shown in Figure 5.1. Because of the difficulty of accurately collecting samples of smaller taxonomic groups such as Amphipoda, Isopoda, and Annelida by trawl or dredge, these groups were not identified in trawl and dredge collections. Only data from airlift suction and Smith-McIntyre grab samples were considered to be quantitative since these methods collected organisms within defined areas (0.1 m^2). Although an attempt was made, using Loran, to tow a uniform distance with the rock dredge and trawl gear, irregular bottom topography precluded consistency of collections.

Data Analysis:

An index of abundance (Musick and McEachran 1972) and mean abundance at each station were used to assess relative dominance of selected species. Chosen as the dominant species were the eight most abundant species by number. Another calculation of relative dominance was performed utilizing the eight species with the greatest biomass.

The Shannon-Wiener or information index of species diversity (Pielou 1975), the evenness component of diversity (Whittaker 1970), and species richness were computed with data from quantitative collections made with airlift suction and grab samplers. Only those species counted in samples rather than weighed were included in the calculation of these indices; colonial invertebrate species and algae were excluded from the analysis. The indices were calculated using pooled replicates for each station. Number of species was used as the expression of diversity for the rock dredge and trawl samples.

Dominance diversity curves (Whittaker 1965) were plotted using data from suction and grab samples to determine species importance in the community. The shape of the curve can be used to determine how resource space of the community is divided (Whittaker 1965). Only species counted in samples rather than weighed were included in this analysis; an importance value associated with colonial organisms and algae was not determined. Therefore, complete division of niche space in the community could not be determined.

Cluster analysis was used to elucidate patterns of similarity among species and collections for both binary data (species presence or absence) collected by qualitative sampling gear (rock dredge and trawl) and abundance data collected by quantitative samplers (airlift suction and Smith-McIntyre grab). Due to core and time constraints of the computer program, data sets were reduced prior to cluster analysis by elimination of species which occurred in only one collection. Only species counted in samples rather than weighed were included in the cluster analysis for the suction and grab collections; colonial invertebrate species and algae were excluded from the analysis. Collections were deleted from the analysis if they contained only one species because of possible confusion of interpretation (Boesch 1977).

Algorithms used with cluster analysis differed for qualitative and quantitative data. The Jaccard coefficient (Clifford and Stephenson 1975, Boesch 1977) was used with the qualitative data collected using dredge and trawl, while the Canberra metric similarity coefficient (Lance and Williams 1966, 1967) was used to cluster quantitative data (following square-root transformation) collected with airlift suction and grab samplers. Normal classifications, in which collections are clustered as entities with species content as attributes, and inverse classifications, in which species are grouped as entities with their presence or abundance in collections as attributes (Williams and Lambert 1961a), were produced for each data set.

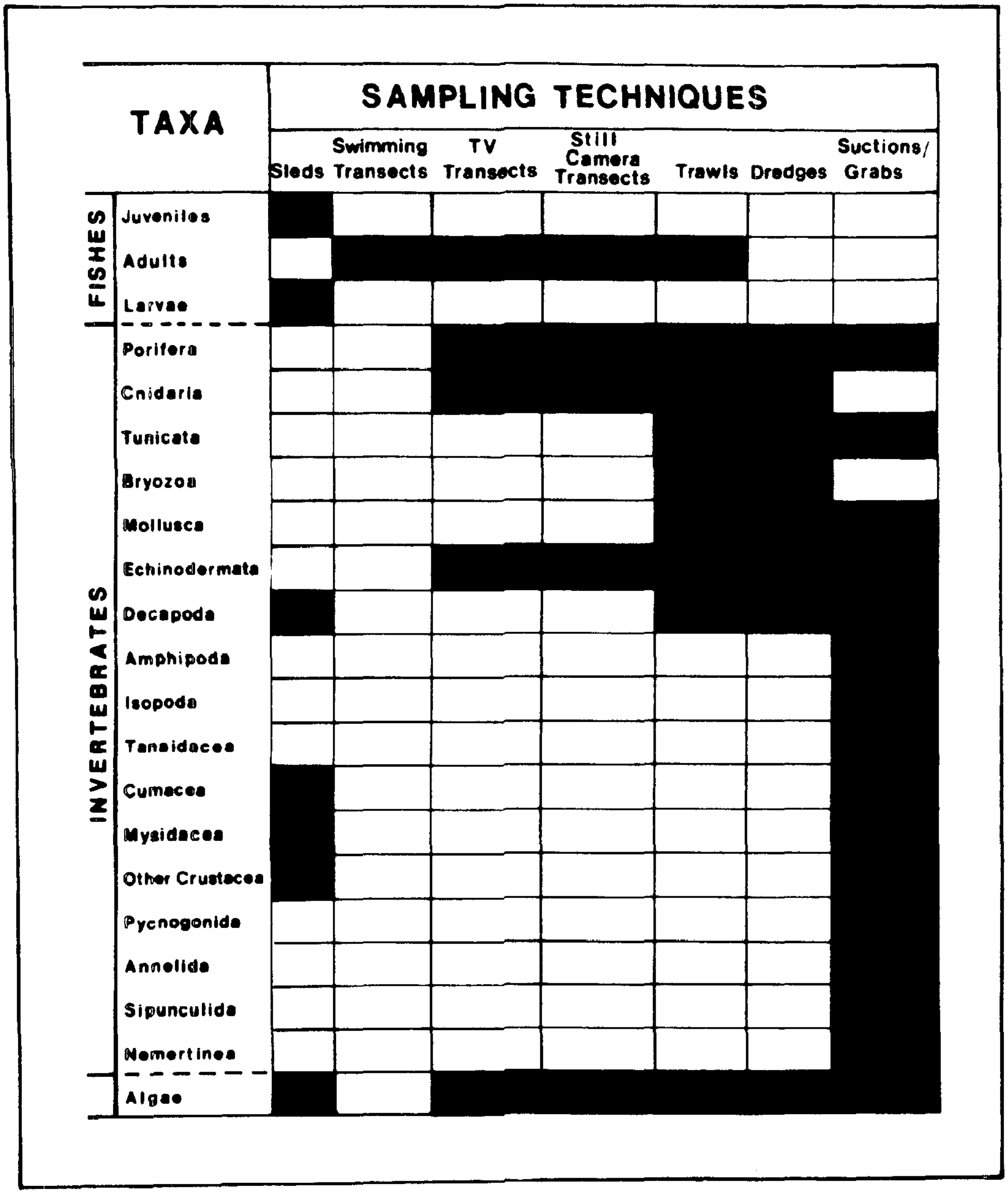

Figure 5.1. Sampling equipment used in the collection of invertebrate, algal, and fish taxa.

Species groups with internal resemblance were chosen from dendrograms formed with inverse cluster analysis by referencing the dendrograms with collection data.

Nodal analysis (Williams and Lambert 1961b, Lambert and Williams 1962) was used to describe differences in the distribution patterns of species associations delineated in inverse (both Canberra and Jaccard) cluster analysis. This analysis expressed the degree to which a collection group and species group coincided, utilizing graded constancy and fidelity values in nodal diagrams (Boesch 1977). The constancy index indicates the degree to which species belonging to particular groups are found in collections which define stations; the fidelity index measures the degree to which species are restricted or limited to collections from a station.

RESULTS

Diver Observations:

IS04 - Invertebrates, particularly *Telesto fructiculosa* and *Vermicularia knorrii*, were concentrated along the ledge drop-off. Over the remainder of the rock surface the distribution of invertebrates was patchy and very sparse, consisting primarily of gorgonian octocorals. There was no evidence of fleshy algal species; clearing away the fine silt covering the ledge revealed bare rock void even of crustose species.

MS04 - Large undercut rocks along the edge of the rock ledges provided crevices and caverns which appeared to serve as refuges for many fish species. High percent cover by algae increased habitat complexity, providing additional protection for fish species. There was no bare rock; the bottom was completely covered with a diversity of seaweed and invertebrate species (see Figures 4.2 and 4.3).

Television Transect Analysis:

Shown in Figure 5.2 is the frequency of occurrence of octocorallian and antipatharian species commonly observed at the study areas. *Lophogorgia hebes* Verrill had similar occurrence at MS04 and OS04, while both *Titanideum frauenfeldii* Kölliker and *Leptogorgia virgulata* Lamarck occurred more frequently at OS04 than MS04. *Stichopathes* sp., an antipatharian coral, was observed only at OS04 (Figure 5.2). *Oculina arbuscula* Verrill, a scleractinian coral, occurred less frequently than octocorals at MS04 and OS04 (Figure 5.3). Sponge species (where only upright sponges were noted) were observed ony at OS04 (Figure 5.3). Analysis of television transects indicated that algae were the dominant canopy group at MS04, whereas Octocorallia predominated in this position at OS04 (Figures 5.2 and 5.3).

Dredge and Trawl Sampling:

Species Composition - Species richness and occurrence at IS04, MS04, and OS04 are shown in the complete species lists tabulated from dredge and trawl collections (Appendices 19-22). We have also listed those species which occurred frequently (in three or more collections) in dredge and trawl collections at all stations (Table 5.1 and 5.2). Due to high relief at IS04 and OS04, trawling over the live bottom areas was not possible without loss of

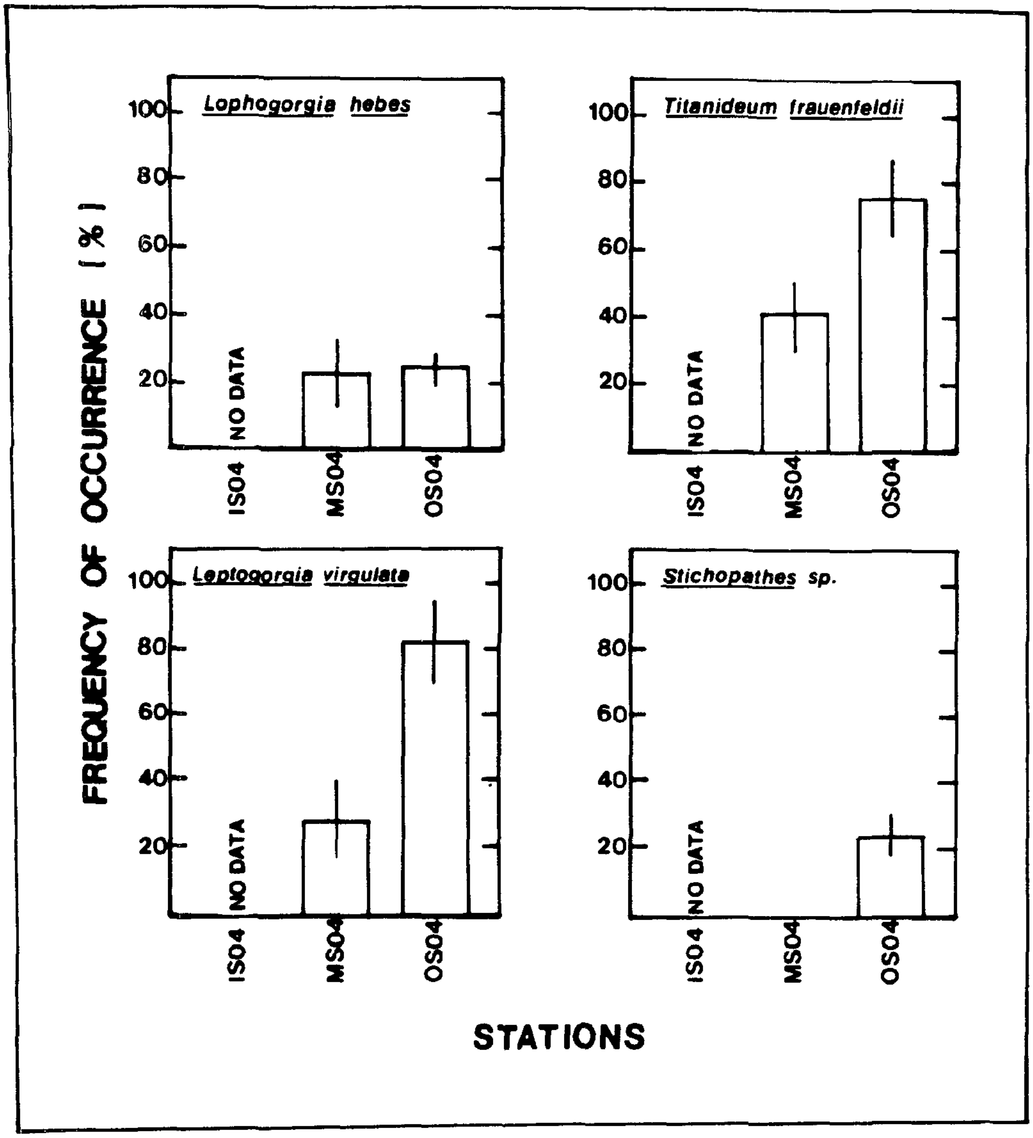

Figure 5.2. Frequency of occurrence (shown as mean percent ± 1 SE) of selected invertebrate species censused in three television transects at each station.

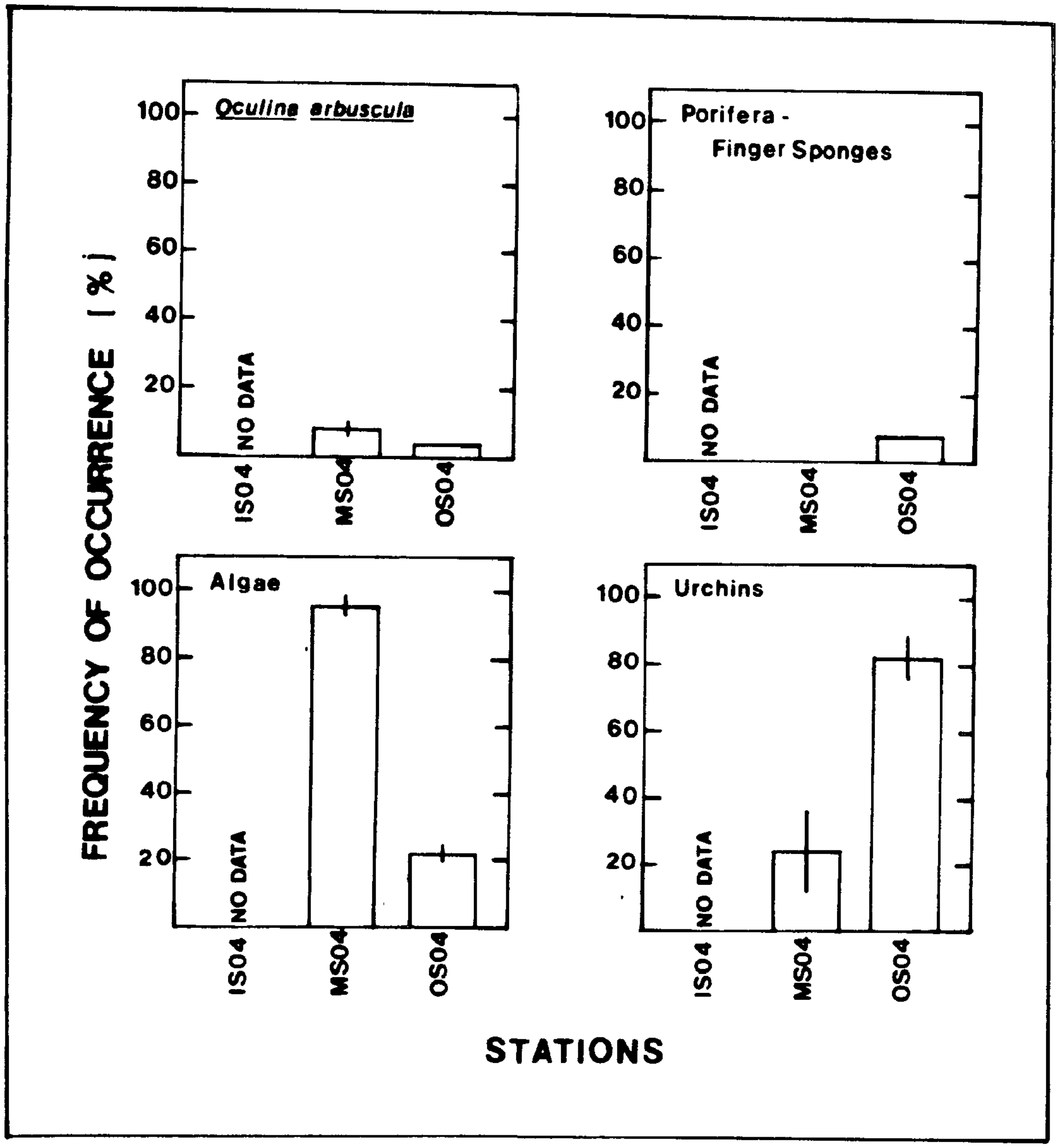

Figure 5.3. Frequency of occurrence (shown as mean percent ± 1 SE) of the coral species Oculina arbuscula and selected taxonomic groups censused in three television transects at each station.

Table 5.1 Ranked list of species occurring in at least half of six dredge samples for all stations for summer 1980.

Rank	Species	Occurrence
1.0	Ophiothrix angulata - Echinodermata	5
3.5	Amphiuridae C - Echinodermata	4
3.5	Arbacia punctulata - Echinodermata	4
3.5	Telesto fruticulosa - Cnidaria	4
3.5	Synalpheus townsendi - Decapoda	4
16.5	Kallymenia perforata - Alga	3
16.5	Soliera tenera - Alga	3
16.5	Gracilaria mammillaris - Algae	3
16.5	Corallina cubensis - Alga	3
16.5	Sargassum filipendula - Alga	3
16.5	Lobophora variegata - Alga	3
16.5	Lithophaga bisculata - Mollusca	3
16.5	Chama congregata - Mollusca	3
16.5	Lyonsia beana - Mollusca	3
16.5	Pteria colymbus - Mollusca	3
16.5	Barbatia candida - Mollusca	3
16.5	Arca imbricata - Mollusca	3
16.5	Vermicularia knorrii - Mollusca	3
16.5	Diodora cayenensis - Mollusca	3
16.5	Amphiodia pulchella - Echinodermata	3
16.5	Ophiactis algicola - Echinodermata	3
16.5	Oculina arbuscula - Cnidaria	3
16.5	Titanideum frauenfeldii - Cnidaria	3
16.5	Megalobrachium soriatum - Decapoda	3
16.5	Pseudomedeus agassizii - Decapoda	3
16.5	Geodia gibberosa - Porifera	3
16.5	Styela partita - Ascideacea	3

Table 5.2 Ranked list of species occurring in at least half of six trawl samples at station MS04 for summer 1980.

Rank	Species	Occurrence
4.0	Soliera tenera - Alga	5
4.0	Sargassum filipendula - Alga	5
4.0	Spatoglossum schroederi - Alga	5
4.0	Dictyopteris hoytii - Alga	5
4.0	Pteria colymbus - Mollusca	5
4.0	Styela plicata - Ascideacea	5
4.0	Molgula occidentalis - Ascideocea	5
9.0	Arca zebra - Mollusca	4
9.0	Halymenia floridana - Alga	4
9.0	Chama congregata - Mollusca	4
16.0	Astrophyton muricatum- Echinodermata	3
16.0	Lytechinus variegatus - Echinodermata	3
16.0	Metapenaeopsis goodei - Decapoda	3
16.0	Chrysymenia enteromorpha - Alga	3
16.0	Sporochnus pedunculatus - Alga	3
16.0	Codium isthmocladum - Alga	3
16.0	Hiatella arctica - Mollusca	3
16.0	Celloporaria magnifica - Bryozoa	3
16.0	Aglaophenia trifida - Cnidaria	3
16.0	Didemnum candidum - Ascideacea	3
16.0	Gracilaria mammillaris - Alga	3

equipment. Therefore, only data from MS04 are presented. Four algal (Soliera tenera, Sargassum filipendula, Spatoglossum schroederi, Dictyopteris hoytii), one molluscan (Pteria colymbus), and two tunicate species (Styela plicata, Molgula occidentalis) were present in five out of six trawl collections at MS04 (Table 5.2). Other molluscan (Arca zebra, Chama congregata) and algal (Halymenia floridana) species also were frequently collected with trawls, which is indicative of their high abundance in this area.

According to the list of frequently occurring species in the six dredge samples (Table 5.1), the echinoderm, Ophiothrix angulata, had a ubiquitous distribution, occurring at all study areas. Other frequently collected species included Amphiuridae C, Arbacia punctulata, Telesto fructiculosa, and Synalpheus townsendi, showing that organisms from motile, attached, and sessile fauna all were collected. Less frequent occurrence of algal and molluscan species in the combined dredge samples from the three study areas reflects limited distribution of these species which predominated at MS04. Using the dredge collections for comparison, the data indicate that MS04 had a greater number of species than IS04 or OS04. The lowest number of species was found at OS04 (Appendices 19-21).

Data presented in Figure 5.4 indicate the percent of species represented in each major taxonomic group of invertebrates and algae sampled with the rock dredge at the three study areas. No species of Ascidiacea, Porifera, or Scleractinia were collected at Station OS04; the highest percentages of species were contributed by Decapoda, Echinodermata, and Mollusca. Both dredge samples at OS04, however, contained few organisms and the percentages calculated are based on a total of only 20 organisms. Thus, these percentages may not be typical of the outer shelf live bottom community, although a similar trend was observed in South Carolina samples (see Volume I). Station IS04 also had a high percentage of species represented in Mollusca (29%) and Decapoda (19%); however, many species of Porifera were also collected at this study area (Figure 5.4). At MS04, taxa with the greatest percentages of species were molluscs and algae; additionally, the groups Porifera, Decapoda, and Echinodermata each contributed greater than 10% of the total number of species. Species were more evenly distributed within the taxonomic groups at MS04 than at either of the other sites (Figure 5.4).

Biomass Distribution - The distribution of biomass within major taxonomic groups (Figure 5.5) is in sharp contrast to species distribution of these groups (Figure 5.4) at all three sites. Whereas species numbers are relatively evenly distributed among the three study areas, each site is dominated by one group in terms of biomass. Scleractinia contributed a tremendous proportion of the biomass (77%) at IS04, whereas Mollusca predominated by weight (70%) at OS04. Both Scleractinia and Mollusca have calcareous parts, however, which were included in biomass measurements. While both Mollusca and algae contributed a large proportion of the biomass at MS04, the seaweeds appeared to dominate in this area, providing greater than 50% of the total biomass (Figure 5.5). Therefore, a different taxonomic group is dominant by weight at each study area. The total biomass at IS04 equaled 3321.9 g; at MS04, 5852.5 g; and at OS04, 0.9 g. Again, at OS04, the biomass percentages may be atypical because of the low number of animals dredged at this station. Total biomass of each taxon is shown in Appendix 23, Volume III.

Community Composition - The dendrogram resulting from the normal (Jaccard) cluster analysis of the six dredge samples (Figure 5.6) indicates that samples collected from each station clustered more tightly to each other than to

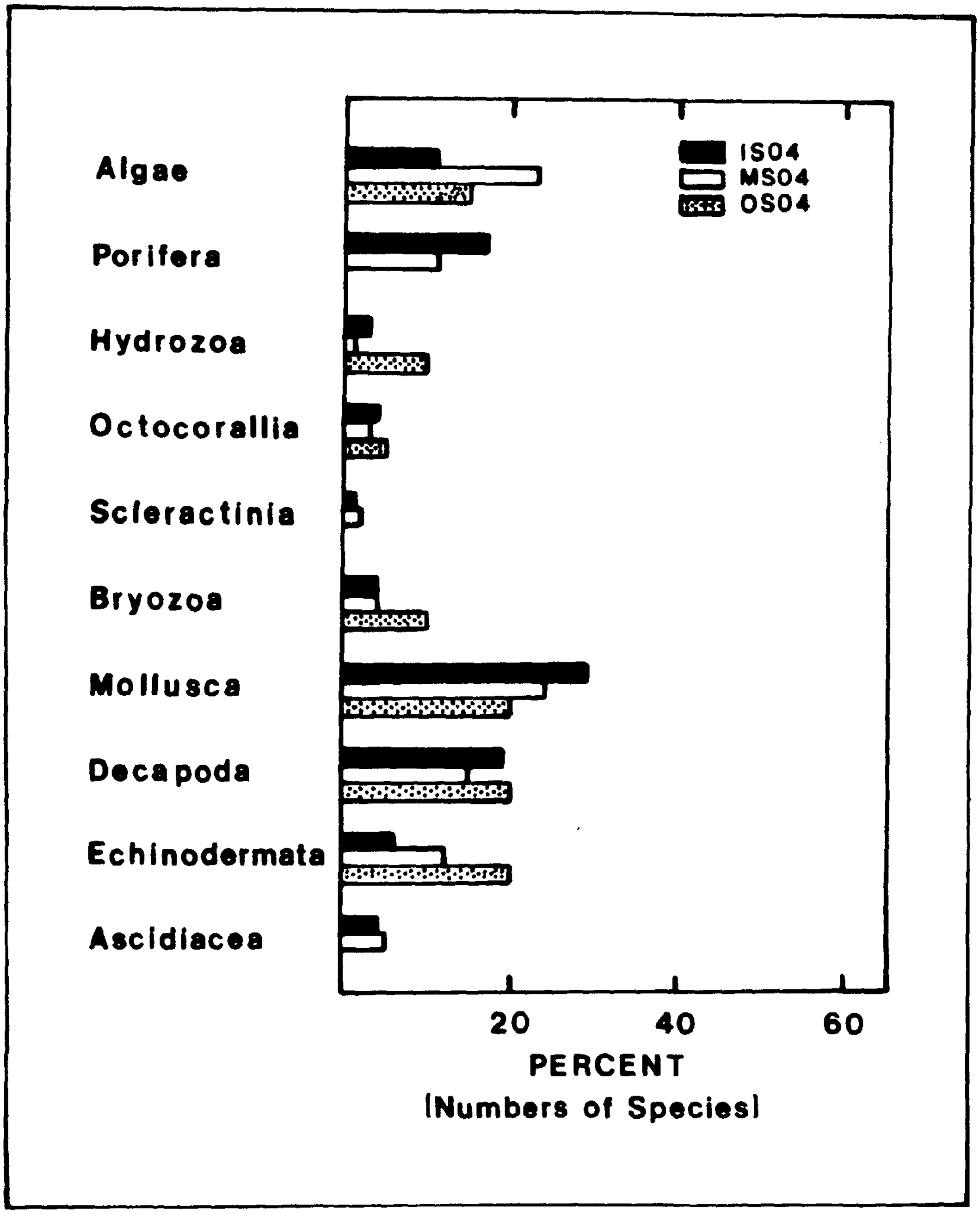

Figure 5.4. Taxonomic composition of invertebrates and algae censused with the Cerame-Vivas rock dredge. Percent values represent the ratio of the number of species in each taxon to the total number of species at each station. Percentages calculated for OS04 were based on only 20 organisms.

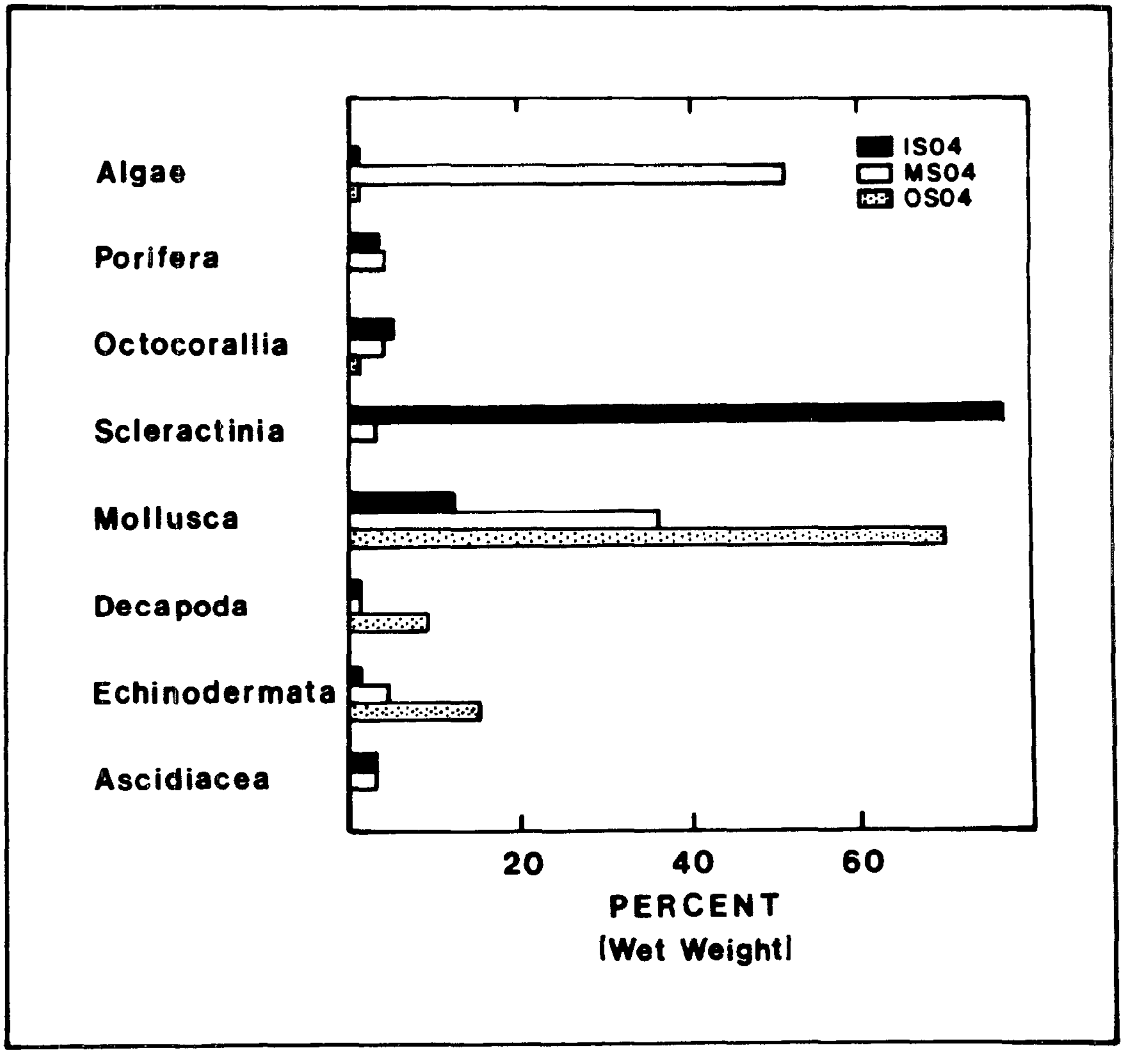

Figure 5.5. Percent of total biomass found in each taxonomic group of invertebrates and algae censused with the Cerame-Vivas rock dredge. Percent values represent the ratio of the weight (grams) of each taxonomic group to the total weight of the catch at each station. Percentages calculated for OS04 are based on a total weight of only 0.9 g.

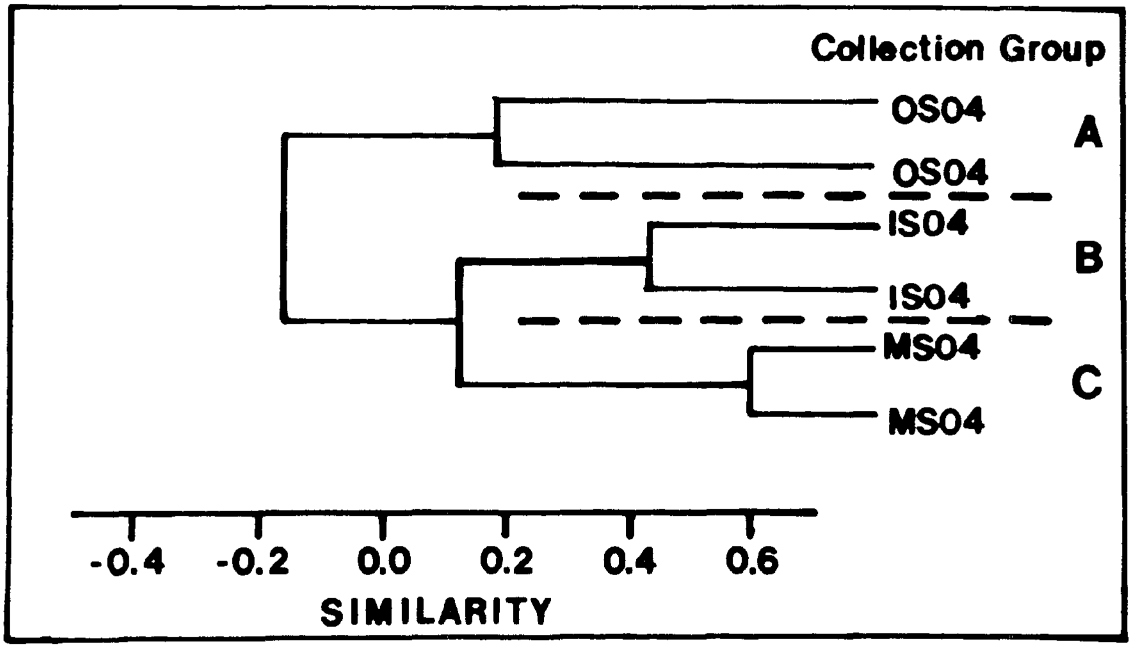

Figure 5.6. Collection associations delineated from normal (Jaccard) cluster analysis of rock dredge samples at IS04, MS04, and OS04.

collections taken at the other study sites, but there was a range in similarity values between replicates. Group C, which included the two dredge collections from MS04, had a similarity value of 0.61; the two dredge samples from OS04 (Group A) clustered at 0.18; and Group B clustered at 0.42. Nonetheless, these values indicate that groups from IS04 and MS04 were more similar to each other than to the OS04 group. This also may be an artifact due to the small sample size at OS04. However, the same grouping of summer dredge samples was observed in South Carolina (see Volume I).

Nine species groupings were delineated from the inverse (Jaccard) cluster analysis of the rock dredge data (Table 5.3), with associations ranging from similarity values of 0.16 to 1.00. The high similarity values (1.0) of some of the species associations indicated geographical or bathymetric restriction of species to one study area (OS04: Group A, MS04: Group G) and the consistent collection of species at two sites (Groups H, I). The weaker associations (Groups D, E) were a reflection of less consistent but ubiquitous distribution of species within collections. The presence of congeneric species within different groups (e.g. Arca imbericata, Group D and A. zebra, Group G, Table 5.3) may indicate similar niches in those groups; but without more information on the ecology of the organisms, nothing definitive can be stated.

The results of the nodal analysis of species associations delineated from the inverse (Jaccard) cluster analysis of the rock dredge samples are shown in Figure 5.7. Group G showed very high constancy at MS04; the species comprising the association were present in both dredge samples at that station. However, since these species were not found in dredge collections at IS04 and OS04 it was surprising that their fidelity value was $<$ 4 (high). While species Groups B and E had very high constancy at OS04 and IS04, respectively, they showed only moderate fidelity in these areas because of the collection of one species in dredge samples from another station. Many species associations (Groups D, F, H, I) had high or very high constancy at both IS04 and MS04, possibly reflecting broad geographic or bathymetric distribution of these species. That species comprising Group A may be limited to cooler waters (in the summer) is indicated by their restriction to IS04 and OS04, the two study sites occurring within the area influenced by the Virginian Current. The low fidelity values for this association are probably a reflection of low abundance of these species at IS04 and OS04, for they were collected in only one dredge sample at each site.

Suction and Grab Sampling:

Species Composition and Abundance - The species collected using suction and grab samplers at the three study areas are shown in Appendices 24-26. Lists of the species ranked by abundance (for those species counted) are given in Tables 5.4 - 5.6. None of the colonial organisms or algae are included in these tables since they were not counted. At IS04 five species had a mean abundance per 0.1 m^2 greater than three individuals, whereas only two species, Prionospio sp. B. and Unciola laminosa, were collected in such abundance at OS04. At MS04 Lembos unicornis and Ophiostigma isocanthum also had a mean abundance per 0.1 m^2 of three or more individuals. Most species at all three sites occurred in very low abundance (Tables 5.4 - 5.6).

The index of abundance, calculated for the eight most numerically dominant species, and an index of biomass, calculated for the eight species dominant by weight from the suction and grab samples, are not accurate methods for assessing the relative abundance of species and biomass because they are affected by the dispersion of numbers and weight among collections (Tables 5.7 and 5.8). For example, Melita appendiculata, which had a total of 100 individuals collected,

Table 5.3 Species associations delineated from inverse (Jaccard) cluster anlaysis of the Cerame-Vivas rock dredge samples (N = 6) taken during summer 1980 at the three study areas. The level of association is given for each grouping. (Alg - Algae; Asc - Ascidiaecea; Bry- Bryozoa; Cnid - Cnidaria; Dec - Decapoda; Ech - Echinodermata; Mol - Mollusca; Por - Porifera)

Group A (1.00)

- Barbatia domingensis - Mol
- Lithophyllum subtenellum - Alg

Group B (0.67)

- Barbatia candida - Mol
- Arcopsis conradiana - Mol

Group C (0.56)

- Galathea rostrata - Dec
- Amphiodia pulchella - Ech
- Ophiactis algicola - Ech

Group D (0.16)

- Synalpheus townsendi - Dec
- Pteria colymbus - Mol
- Parasmittina spathulata - Bry
- Telesto fruticulosa - Cnid
- Arbacia punctulata - Asc
- Ophiothrix angulata - Ech
- Amphiuridae C - Ech
- Megalobrachum soriatum - Dec
- Arca imbricata - Mol
- Styela partita - Asc
- Pisania tincta - Mol

Group E (0.45)

- Pseudomedaeus agassizii - Dec
- Haliplanella luciae - Cnid
- Aplidium constellatum - Asc
- Ascidia interrupta - Asc
- Tenaciella obliqua - Por

Group F (0.31)

- Leptogorgia virgulata - Cnid
- Nassarius albus - Mol
- Vermicularia knorrii - Mol
- Lithophaga bisulcata - Mol
- Geodia gibberosa - Por
- Titanideum frauenfeldii - Cnid
- Oculina arbuscula - Cnid

Group G (1.00)

- Galaxaura obtusata - Alg
- Agardhinula browneae - Alg
- Molgula occidentalis - Asc
- Zonaria tournefortii - Alg
- Halymenia agardhii - Alg
- Codium isthmocladum - Alg
- Dictyopteris hoytii - Alg
- Botula fusca - Mol
- Lithophaga aristata - Mol
- Arca zebra - Mol
- Hiatella arctica - Mol
- Crepidula aculeata - Mol
- Gastrochaena hians - Mol
- Stylopoma informata - Bry
- Celloporaria albirostris - Bry
- Ophiopsila riisei - Ech
- Ophiactis savignyi - Ech
- Amphiuridae A - Ech
- Ophiostigma isocanthum - Ech
- Merriamium tortugasensis - Por

Group H (1.00)

- Aligena elevata - Mol
- Dictyota dichotoma - Alg
- Pilumnus sayi - Dec
- Ostrea equestris - Mol
- Chione grus - Mol
- Dardanus fucosus - Dec

Group I (1.00)

- Soliera tenera - Alg
- Kallymenia perforata - Alg
- Diodora cayenensis - Mol
- Corallina cubensis - Alg
- Gracilaria mammillaris - Alg
- Lobophora variegata - Alg
- Sargassum filipendula - Alg
- Lyonsia beana - Mol
- Chama congregata - Mol

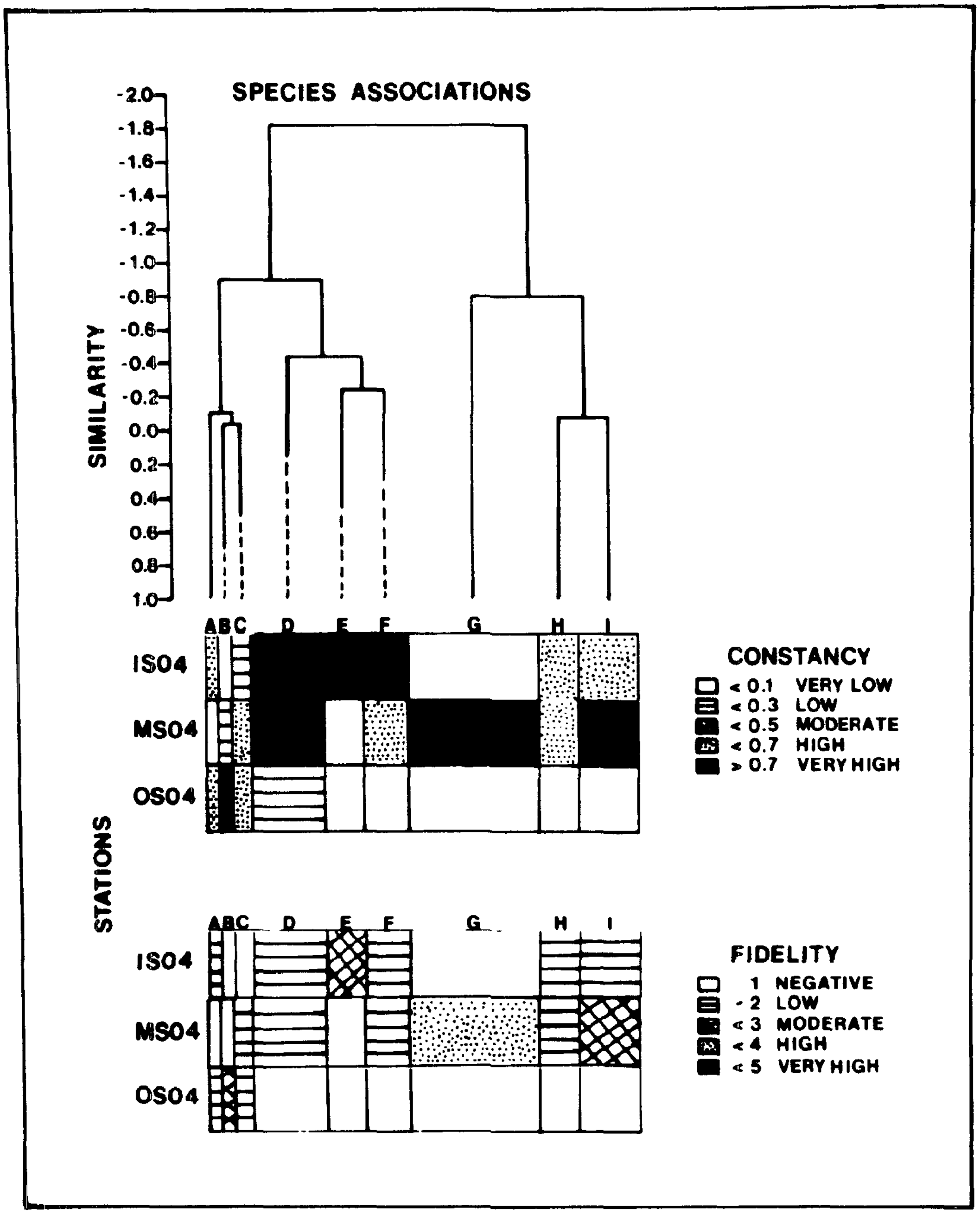

Figure 5.7. Nodal analysis of species associations delineated from the inverse (Jaccard) cluster analysis of the six rock dredge samples taken at IS04, MS04, and OS04. Levels of constancy and fidelity are given for each species association by station below the hierarchical portion of the dendrogram which was generated in the inverse cluster analysis. Dashed lines begin at the species groups similarity index. Width of species groups is proportional to the number of species in the association.

Table 5.4 Ranked species list for five airlift suction samples taken at IS04 during summer 1980 sampling. Total numbers of individuals collected and means (number 0.1 m^{-2} + 1 S.E.) are given for species which were counted rather than weighed in the collection. (Amph - Amphipoda; Arth - Arthropoda; Dec - Decapoda; Ech - Echinodermata; Mol - Mollusca; Pol - Polychaeta)

Species	Total Number	$\bar{x}$	SE	Rank by Number
Melita appendiculata - Amph	98	19.6	18.12	1.0
Lembos smithi - Amph	64	12.8	11.10	2.0
Anachis lafresnayi - Mol	45	9.0	3.00	3.0
Ophiothrix angulata - Ech	17	3.4	1.50	4.0
Hydroides uncinata - Pol	16	3.2	0.86	5.0
Urosalpinx sp. A - Mol	10	2.0	0.94	6.0
Arbacia punctulata - Ech	9	1.8	0.66	7.0
Nassarius albus - Mol	8	1.6	1.12	8.0
Amphiuridae C - Ech	7	1.4	1.16	9.5
Mitrella lunata - Mol	7	1.4	0.50	9.5
Tanaidacea A - Arth	6	1.2	1.20	12.0
Abra aequalis - Mol	6	1.2	0.96	12.0
Polydora caeca - Pol	6	1.2	1.20	12.0
Maera williamsi - Amph	5	1.0	1.00	14.0
Pelia mutica - Dec	4	0.8	0.80	16.5
Lembos unicornis - Amph	4	0.8	0.80	16.5
Gammoropsis sp. - Amph	4	0.8	0.58	16.5
Cistenides gouldii - Pol	4	0.8	0.80	16.5
Sicyonia laevigata - Dec	3	0.6	0.60	24.5
Pseudomedaeus agassizii - Dec	3	0.6	0.40	24.5
Unciola laminosa - Amph	3	0.6	0.60	24.5
Erichthonius brasiliensis - Amph	3	0.6	0.40	24.5
Vermicularia knorrii - Mol	3	0.6	0.40	24.5
Eulalia macroceros - Pol	3	0.6	0.60	24.5
Protula tubularia - Pol	3	0.6	0.60	24.5
Hydroides dianthus - Pol	3	0.6	0.60	24.5
Odontosyllis fulgurans - Pol	3	0.6	0.60	24.5
Polydora plena - Pol	3	0.6	0.40	24.5
Dorvillea sociabilis - Pol	3	0.6	0.40	24.5
Turbonilla sp. A - Pol	3	0.6	0.24	24.5
Sicyonia sp. A - Dec	2	0.4	0.40	39.5
Micropanope sp. - Dec	2	0.4	0.24	39.5
Corbula barrattiana - Mol	2	0.4	0.40	39.5
Anachis obesa - Mol	2	0.4	0.40	39.5
Nucula proxima - Mol	2	0.4	0.24	39.5
Pteria colymbus - Mol	2	0.4	0.24	39.5
Anomia simplex - Mol	2	0.4	0.40	39.5
Chione grus - Mol	2	0.4	0.24	39.5
Gouldia cerina - Mol	2	0.4	0.40	39.5
Seila adamsi - Mol	2	0.4	0.40	39.5
Pisania tincta - Mol	2	0.4	0.40	39.5
Polycirrus sp. - Pol	2	0.4	0.40	39.5
Sabellaria floridensis - Pol	2	0.4	0.24	39.5
Sabellaria vulgaris beaufortensis - Pol	2	0.4	0.40	39.5
Sthenelais boa - Pol	2	0.4	0.40	39.5
Loimia medusa - Pol	2	0.4	0.40	39.5

Table 5.4 (Continued)

Species	Total Number	$\bar{x}$	SE	Rank by Number
Marphysa sp. - Pol	2	0.4	0.40	39.5
Lepidonotus variabilis - Pol	2	0.4	0.24	39.5
Lysmata sp. - Dec	1	0.2	0.20	59.5
Neopontonides beaufortensis - Dec	1	0.2	0.20	59.5
Galathea rostrata - Dec	1	0.2	0.20	59.5
Macrocoeloma camptocerum - Dec	1	0.2	0.20	59.5
Heterocrypta granulata - Dec	1	0.2	0.20	59.5
Megalobrachium sorbitum - Dec	1	0.2	0.20	59.5
Pinnotheres sp. A - Dec	1	0.2	0.20	59.5
Melitidae - Amph	1	0.2	0.20	59.5
Elasmopus sp. B - Amph	1	0.2	0.20	59.5
Photis sp. - Amph	1	0.2	0.20	59.5
Amphiuridae A - Ech	1	0.2	0.20	59.5
Amphiodia pulchella - Ech	1	0.2	0.20	59.5
Acteocina candei - Mol	1	0.2	0.20	59.5
Marginellidae A - Mol	1	0.2	0.20	59.5
Musculus lateralis - Mol	1	0.2	0.20	59.5
Arcopsis adamsi - Mol	1	0.2	0.20	59.5
Suturoglypta iontha - Mol	1	0.2	0.20	59.5
Pitar fulminatus - Mol	1	0.2	0.20	59.5
Tellina aequistriata - Mol	1	0.2	0.20	59.5
Colubraria lanceolata - Mol	1	0.2	0.20	59.5
Aspella senex - Mol	1	0.2	0.20	59.5
Rissoina catesbyana - Mol	1	0.2	0.20	59.5
Modiolus americanus - Mol	1	0.2	0.20	59.5
Laevicardium multilineatum - Mol	1	0.2	0.20	59.5
Pyrogocythara metria - Mol	1	0.2	0.20	59.5
Triphora nigrocincta - Mol	1	0.2	0.20	59.5
Turbonilla sp. B - Mol	1	0.2	0.20	59.5
Epitonium angulatum - Mol	1	0.2	0.20	59.5
Lumbrineris latreilli - Pol	1	0.2	0.20	59.5
Pista palmata - Pol	1	0.2	0.20	59.5
Harmothoe aculeata - Pol	1	0.2	0.20	59.5

Table 5.5 Ranked species list for five airlift suction samples taken at MS04 during summer 1980 sampling. Total numbers of individuals collected and means (number 0.1 m^{-2} + 1 S.E.) are given for species which were counted rather than weighed in the collection. (Amph - Amphipoda; Arth - Arthropoda; Dec - Decapoda; Ech - Echinodermata; Iso - Isopoda; Mol - Mollusca; Pol - Polychaeta; Pyc - Pycnogonida)

Species	Total Number	$\bar{x}$	SE	Rank by Number
Lembos unicornis - Amph	35	7.0	3.21	1.0
Ophiostigma isocanthum - Ech	15	3.0	1.22	2.0
Amphithoe sp. A - Amph	13	2.6	0.24	3.0
Phyllocarida A - Arth	11	2.2	1.11	4.0
Ophiactis algicola - Ech	8	1.6	0.67	5.0
Ampelisca verrilli - Amph	7	1.4	0.74	6.0
Chione grus - Mol	6	1.2	0.73	8.0
Eunice vittoto - Pol	6	1.2	0.73	8.0
Hydroides crucigera - Pol	6	1.2	0.58	8.0
Alpheus formosus - Dec	5	1.0	0.63	11.5
Mithrax sp. A - Dec	5	1.0	0.63	11.5
Ophiothrix angulata - Ech	5	1.0	0.44	11.5
Gouldia cerina - Mol	5	1.0	0.44	11.5
Melita sp. A - Amph	4	0.8	0.80	15.0
Amphiodia pulchella - Ech	4	0.8	0.58	15.0
Nassarina glypta - Mol	4	0.8	0.48	15.0
Micropanope sp. - Dec	3	0.6	0.40	23.8
Liljeborgia sp. A - Amph	3	0.6	0.60	23.8
Erichsonella filiformis - Iso	3	0.6	0.24	23.8
Platynereis dumerilii - Pol	3	0.6	0.60	23.8
Lumbrineris inflata - Pol	3	0.6	0.24	23.8
Uniciola lominosa - Amph	3	0.6	0.40	23.8
Pitho lherminieri - Dec	2	0.4	0.40	28.9
Pontoniinae A - Dec	2	0.4	0.40	28.9
Erichthonius brasiliensis - Amph	2	0.4	0.24	28.9
Melphidippidea A - Amph	2	0.4	0.40	28.9
Podocerus sp. A - Amph	2	0.4	0.24	28.9
Paracerceis caudata - Iso	2	0.4	0.40	28.9
Melita appendiculata - Amph	2	0.4	0.24	28.9
Anoplodactylus insignis - Pyc	2	0.4	0.40	28.9
Amphiuridae A - Ech	2	0.4	0.24	28.9
Arca zebra - Mol	2	0.4	0.40	28.9
Tellina sp. A - Mol	2	0.4	0.24	28.9
Hydroides sp. B - Pol	2	0.4	0.40	28.9
Glycera tesselota - Pol	2	0.4	0.24	28.9
Hydroides sp. A - Pol	2	0.4	0.24	28.9
Websterinereis tridentata - Pol	2	0.4	0.40	28.9
Subadyte pellucida - Pol	2	0.4	0.40	28.9
Odontosyllis fulgurons - Pol	2	0.4	0.40	28.9
Syllis hyalina - Pol	2	0.4	0.40	28.9
Eunice websteri - Pol	2	0.4	0.40	28.9
Sicyonia laevigata - Dec	1	0.2	0.20	66.8
Ethusa mascarone americana - Dec	1	0.2	0.20	66.8
Homola barbata - Dec	1	0.2	0.20	66.8

Table 5.5 Continued

Species	Total Number	$\bar{x}$	SE	Rank by Number
Cronius ruber - Dec	1	0.2	0.20	66.8
Mithrax forceps - Dec	1	0.2	0.20	66.8
Macrocolloma trispnosum nodipes - Dec	1	0.2	0.20	66.8
Tanaidacea B - Arth	1	0.2	0.20	66.8
Accalanthura crenulata - Iso	1	0.2	0.20	66.8
Heterophlias seclusus - Arth	1	0.2	0.20	66.8
Leucothoe spinicarpa - Amph	1	0.2	0.20	66.8
Elasmopus sp. A - Amph	1	0.2	0.20	66.8
Leptocheirus sp. A - Amph	1	0.2	0.20	66.8
Lysianassidae A - Amph	1	0.2	0.20	66.8
Lytechinus variegatus - Ech	1	0.2	0.20	66.8
Arbacia punctulata - Ech	1	0.2	0.20	66.8
Amphiuridae B - Ech	1	0.2	0.20	66.8
Ophiocnida scabrivscula - Ech	1	0.2	0.20	66.8
Ophiolepidinae A - Ech	1	0.2	0.20	66.8
Amphiuridae C - Ech	1	0.2	0.20	66.8
Eucidaris tribuloides - Ech	1	0.2	0.20	66.8
Pseudothyone belli - Ech	1	0.2	0.20	66.8
Gastrochaena hians - Mol	1	0.2	0.20	66.8
Nassarius albus - Mol	1	0.2	0.20	66.8
Musculus lateralis - Mol	1	0.2	0.20	66.8
Strombiformis bilineatus - Mol	1	0.2	0.20	66.8
Pseudochama radians - Mol	1	0.2	0.20	66.8
Mangelia (Glyphoturris) rugirima - Mol	1	0.2	0.20	66.8
Chione intapurpurea - Mol	1	0.2	0.20	66.8
Tellina versicolor - Mol	1	0.2	0.20	66.8
Thracia sp. A - Mol	1	0.2	0.20	66.8
Montacuta sp. A - Mol	1	0.2	0.20	66.8
Lyonsia beana - Mol	1	0.2	0.20	66.8
Modiolus americanus - Mol	1	0.2	0.20	66.8
Pisania tincta - Mol	1	0.2	0.20	66.8
Marginella roscida - Mol	1	0.2	0.20	66.8
Varicorbula operculata - Mol	1	0.2	0.20	66.8
Turbonilla sp. A - Mol	1	0.2	0.20	66.8
Pista palmata - Pol	1	0.2	0.20	66.8
Pomatoceros americanus - Pol	1	0.2	0.20	66.8
Syllis alternata - Pol	1	0.2	0.20	66.8
Toima medusa - Pol	1	0.2	0.20	66.8
Eurythoe complanata - Pol	1	0.2	0.20	66.8
Cirratulus sp. A - Pol	1	0.2	0.20	66.8
Harmothoe aculeata - Pol	1	0.2	0.20	66.8
Polydora commensalis - Pol	1	0.2	0.20	66.8
Ceratoncreis verispedata - Pol	1	0.2	0.20	66.8
Marphysa sp. - Pol	1	0.2	0.20	66.8
Eulalia sanguinea - Pol	1	0.2	0.20	66.8
Polycirrus carolinensus - Pol	1	0.2	0.20	66.8
Syllis spongicola - Pol	1	0.2	0.20	66.8

Table 5.6 Ranked species list for five Smith-McIntyre grab samples taken at OS04 during summer 1980 sampling. Total numbers of individuals collected and means (number 0.1 m^{-2} + 1 S.E.) are given for species which were counted rather than weighed in the collection. (Amph - Amphipoda; Arth - Arthropoda; Dec - Decapoda; Ech - Echinodermata; Iso - Isopoda; Mol - Mollusca; Pol - Polychaeta)

Species	Total Number	$\bar{x}$	SE	Rank by Number
Prionospio sp. B - Pol	23	4.6	2.85	1.0
Unciola laminosa - Amph	21	4.2	3.96	2.0
Aglaophomus verrilli - Pol	8	1.6	1.60	3.0
Munida irrasa - Dec	7	1.4	1.40	4.0
Pomatoceros americanus - Pol	6	1.2	1.20	6.0
Travisia parva - Pol	6	1.2	0.80	6.0
Glycera tesselata - Pol	6	1.2	0.97	6.0
Onuphis nebulosa - Pol	5	1.0	0.63	8.0
Arbacia punctulata - Pol	4	0.8	0.37	11.5
Platynereis dumerilii - Pol	4	0.8	0.80	11.5
Chone americanus - Pol	4	0.8	0.80	11.5
Glycera papillosa - Pol	4	0.8	0.58	11.5
Nephtys incisa - Pol.	4	0.8	0.80	11.5
Paraonis sp. - Pol	4	0.8	0.80	11.5
Photis macrocoxa - Amph	3	0.6	0.40	17.0
Semele nuculoides - Mol	3	0.6	0.60	17.0
Tellina versicolor - Mol	3	0.6	0.60	17.0
Corbula dietziana - Mol	3	0.6	0.40	17.0
Harmothoe aculeata - Pol	3	0.6	0.24	17.0
Horoloanthura irpex - Iso	2	0.4	0.40	23.5
Abra aequalis - Mol	2	0.4	0.24	23.5
Gouldia cerina - Mol	2	0.4	0.40	23.5
Abra lioica - Mol	2	0.4	0.40	23.5
Crassinella sp. A - Mol	2	0.4	0.40	23.5
Phyllodoce sp. A - Pol	2	0.4	0.24	23.5
Armandia noculota - Pol	2	0.4	0.40	23.5
Eulalia sanguinea - Pol	2	0.4	0.40	23.5
Hypoconcha arcuata - Dec	1	0.2	0.20	49.0
Heterocrypta granulata - Dec	1	0.2	0.20	49.0
Liljeborgia sp. A - Amph	1	0.2	0.20	49.0
Erichthonius brasiliensis - Amph	1	0.2	0.20	49.0
Pananthura formosa - Iso	1	0.2	0.20	49.0
Leptocheirus sp. B - Amph	1	0.2	0.20	49.0
Unciola dissimilis - Amph	1	0.2	0.20	49.0
Ophiothrix angulata - Ech	1	0.2	0.20	49.0
Amphiuridae A - Ech	1	0.2	0.20	49.0
Amphiuridae C - Ech	1	0.2	0.20	49.0
Vermicularia knorrii - Mol	1	0.2	0.20	49.0
Semele bellastriata - Mol	1	0.2	0.20	49.0
Epitonium krebsii - Mol	1	0.2	0.20	49.0
Atys caribaea - Mol	1	0.2	0.20	49.0
Nassarius albus - Mol	1	0.2	0.20	49.0
Plicatula gibbosa - Mol	1	0.2	0.20	49.0
Mangelia (Glyphoturris) rugirima - Mol	1	0.2	0.20	49.0
Semele purpurascens - Mol	1	0.2	0.20	49.0
Nassarina glypta - Mol	1	0.2	0.20	49.0

Table 5.6 (Continued)

Species	Total Number	$\bar{x}$	SE	Rank by Number
Marginella virginiana - Mol	1	0.2	0.20	49.0
Arcopsis conradiana - Mol	1	0.2	0.20	49.0
Tricolia thallassicola - Mol	1	0.2	0.20	49.0
Solariella sp. A - Mol	1	0.2	0.20	49.0
Cylichna verrillii - Mol	1	0.2	0.20	49.0
Turbonilla sp. A - Mol	1	0.2	0.20	49.0
Diplodonta sp. A - Mol	1	0.2	0.20	49.0
Crassinella lunulata - Mol	1	0.2	0.20	49.0
Potamilla sp. A - Pol	1	0.2	0.20	49.0
Protula tubularia - Pol	1	0.2	0.20	49.0
Antinoella sarsi - Pol	1	0.2	0.20	49.0
Pionosyllis uraga - Pol	1	0.2	0.20	49.0
Glycera americana - Pol	1	0.2	0.20	49.0
Protodorvillea kefersteini - Pol	1	0.2	0.20	49.0
Goniala tires - Pol	1	0.2	0.20	49.0
Lumbrineris latreilli - Pol	1	0.2	0.20	49.0
Hydroides sp. A - Pol	1	0.2	0.20	49.0
Drilonereis longa - Pol	1	0.2	0.20	49.0
Syllis cornuta - Pol	1	0.2	0.20	49.0
Opis thodonta - Pol	1	0.2	0.20	49.0
Syllis spongicola - Pol	1	0.2	0.20	49.0
Aricidea cerrutii - Pol	1	0.2	0.20	49.0
Paraprionospio pinnata - Pol	1	0.2	0.20	49.0
Syllis hyalina - Pol	1	0.2	0.20	49.0

Table 5.7 Index of abundance $[\frac{1}{n} \sum^{n} \log_e (x + 1)]$ calculated for the eight most abundant (numerically dominant) species collected with airlift suction and Smith-McIntyre grab samplers at IS04, MS04 and OS04 during summer 1980 (n = 14). The number of individuals per collection is given as an indication of the dispersion among samples. If a collection number is not given for a species, no individuals were collected in that sample.

Species	Coll. #	Ind./coll.	Index of Abundance
Anachis lafresnayi	9025	6	0.78
	9026	21	
	9027	6	
	9031	6	
	9032	6	
Lembos unicornis	9007	3	0.71
	9008	10	
	9011	18	
	9012	4	
	9031	4	
Ophiothrix angulata	9006	2	0.70
	9007	2	
	9011	1	
	9026	2	
	9027	3	
	9031	9	
	9032	3	
	9060	1	
Melita appendiculata	9007	1	0.60
	9012	1	
	9027	1	
	9031	92	
	9032	2	
Unciola laminosa	9007	1	0.49
	9011	2	
	9031	3	
	9061	20	
	9062	1	
Lembos smithi	9027	1	0.49
	9031	57	
	9032	6	
Hydroides uncinata	9025	3	0.46
	9026	5	
	9027	4	
	9031	4	
Prionospio sp. B	9062	13	0.36
	9064	10	

Table 5.8 Index of biomass $[\frac{1}{n}\sum_{1}^{n} \log_e (x + 1)]$ calculated for the eight most abundant (dominant by weight) species collected with airlift suction and Smith-McIntyre grab samplers at IS04, MS04 and OS04 during summer 1980 (n = 14). For each species the grams per collection are given as an indication of the dispersion among samples. If a collection number is not given for a species, there was zero weight for that sample.

Species	Coll. #	grams/coll.	Index of Abundance
Zonaria tournefortii	9006	1.84	1.14
	9007	31.00	
	9008	50.13	
	9011	51.42	
	9012	35.17	
Corallina cubensis	9006	1.79	.95
	9007	9.00	
	9008	13.71	
	9011	22.39	
	9012	61.09	
	9027	.01	
Soliera tenera	9006	4.57	.61
	9007	31.00	
	9008	5.53	
	9011	3.70	
Lobophura variegata	9007	3.19	.41
	9008	4.87	
	9011	2.13	
	9012	3.24	
Sargassum filipendula	9007	18.22	.82
	9008	10.63	
	9011	2.89	
	9012	105.76	
Dictyopteris hoytii	9008	42.23	.58
	9011	13.65	
	9012	4.16	
Ircinia campana	9006	26.19	.24
Eucheuma isiforme	9006	12.43	.21
	9012	.47	

had an index of abundance of 0.60; whereas Ophiothrix angulata had an index of abundance of 0.70 and a total of 23 individuals in all samples (Table 5.7). Similarly, Sargassum filipendula (total weight collected = 137.50 g) had a lower index of biomass (0.82) than Corallina cubensis (total weight collected = 107.99 g; index of abundance = 0.95) (Table 5.8). However, both indices can be used to compare abundance and biomass of a species between stations or at different seasons (see Volume I).

Instead, mean abundance (number per 0.1 m^2) and mean biomass (grams per 0.1 m^2) were used as relative measures of species dominance collected with airlift suction and Smith-McIntyre grab samples (Tables 5.9 and 5.10). The abundance and biomass of each species are shown by station; for all species, dominance is restricted to one study area. No species had high abundance or biomass at all stations. Therefore, all the dominant species had fairly restricted geographical or bathymetric distribution, reflecting narrow tolerance of widely ranging environmental conditions found at the three locations. For example, Melita appendiculata, Lembos unicornis, and Prionospio sp. B were the dominant species by number at IS04, MS04, and OS04, respectively. Only at IS04 was dominance shared, with Melita appendiculata, Lembos smithi, and Anachis lafresnayi occurring in relatively high abundance (Table 5.9). The surprising pattern of dominance by weight was that the eight dominant species occurred at MS04, and all but one (Ircinia campana) were algal species (Table 5.10). The dramatic dominance by the algal species indicates their importance to community composition at MS04 and suggests that exclusion of these species from any analysis of community diversity and dominance may bias results.

Species and Dominance Diversity - The number of species (S), Shannon-Wiener diversity index (H'), and associated evenness (J') estimates for each collection made using airlift suction and grab samplers at the three study areas are shown in Table 5.11. Pooled species diversities for each station indicate that MS04 had the highest (5.62), IS04 the lowest (4.20), and OS04 an intermediate (5.35) diversity estimate. According to the evenness estimate, number of individuals was less uniformly distributed among species at IS04 than the other two stations (Table 5.11).

Dominance diversity curves computed for airlift suction and Smith-McIntyre grab collections for species which were counted rather than weighed are shown in Figures 5.8 - 5.10. All three curves are influenced greatly by the large numbers of species (49-70) represented by only one or two individuals and by the small numbers of species (1-2) represented by more than 16 individuals. These curves apparently do not fit any of the hypothetical curves which attempt to explain dominance diversity relationships (Whittaker 1965, 1970).

Community Composition - Results of the normal (Canberra) cluster analysis of the suction and grab samples collected at the three study sites are shown in Figure 5.11. Most of the organisms taken in the suction and grab collections (colonial organisms and algae) had been deleted prior to the cluster analysis and these sample groupings were generated from data where species were enumerated. All samples taken at IS04 clustered at 0.085 (Group D) and all but one sample (No. 809006) taken at MS04 clustered at 0.19 (Group A), indicating that samples taken within a station were more similar to one another than to samples taken at the other stations. That is, replicates were fairly similar within stations. Collection No. 809006 and 809060, which were samples taken at MS04 and OS04, respectively, clustered (Group B) due to an artifact of low species number in each collection. Both Ophiothrix angulata and Turbonilla sp. A

Table 5.9 Mean abundance (number $0.1\ m^{-2} \pm 1$ S.E.) of the eight dominant species (by number) collected at all three study areas with airlift suction (IS04, MS04: n = 5) and grab (OS04: n = 4) samplers. Abundance of these species is shown by station.

	IS04	MS04	OS04
Melita appendiculata	19.60 ± 18.17	.40 ± .20	0
Lembos smithi	12.80 ± 11.14	0	0
Anachis lafresnayi	9.00 ± 3.00	0	0
Prionospio sp. B	0	0	5.20 ± 2.67
Ophiothrix angulata	3.40 ± 1.51	1.0 ± .44	.20 ± .20
Lembos unicornis	.80 ± .80	7.00 ± 3.02	0
Unciola laminosa	.60 ± .60	.60 ± .60	4.20 ± 3.95
Hydroides uncinata	3.2 ± .86	0	0

Table 5.10 Mean biomass (grams 0.1 m^{-2} $\pm$ 1 S.E.) of the eight dominant species (by weight) collected at all three study areas with airlift suction (IS04, MS04: n = 5) and grab (OS04: n = 4) samplers. Biomass of these species is shown by station.

	IS04	MS04	OS04
Zonaria tournefortii	0	33.91 $\pm$ 8.97	0
Sargassum filipendula	0	27.50 $\pm$ 19.78	0
Corallina cubensis	< 0.01	21.60 $\pm$ 10.45	0
Dictyopteris hoytii	0	12.01 $\pm$ 7.98	0
Soliera tenera	0	8.96 $\pm$ 5.60	0
Ircinia campana	0	5.24 $\pm$ 5.25	0
Lobophora variegata	0	2.69 $\pm$ 0.80	0
Eucheuma isiforme	0	2.58 $\pm$ 2.47	0

Table 5.11 Number of species (S), Shannon-Wiener species diversity (H'), evenness index (J'), species richness index (SR), and total number of individuals (N) for airlift suction and grab collections at IS04, MS04, and OS04.

	IS04	MS04	OS04
S	79	92	70
H'	4.20	5.62	5.35
J'	0.67	0.86	0.87
SR	12.90	16.53	13.29
N	423	246	180

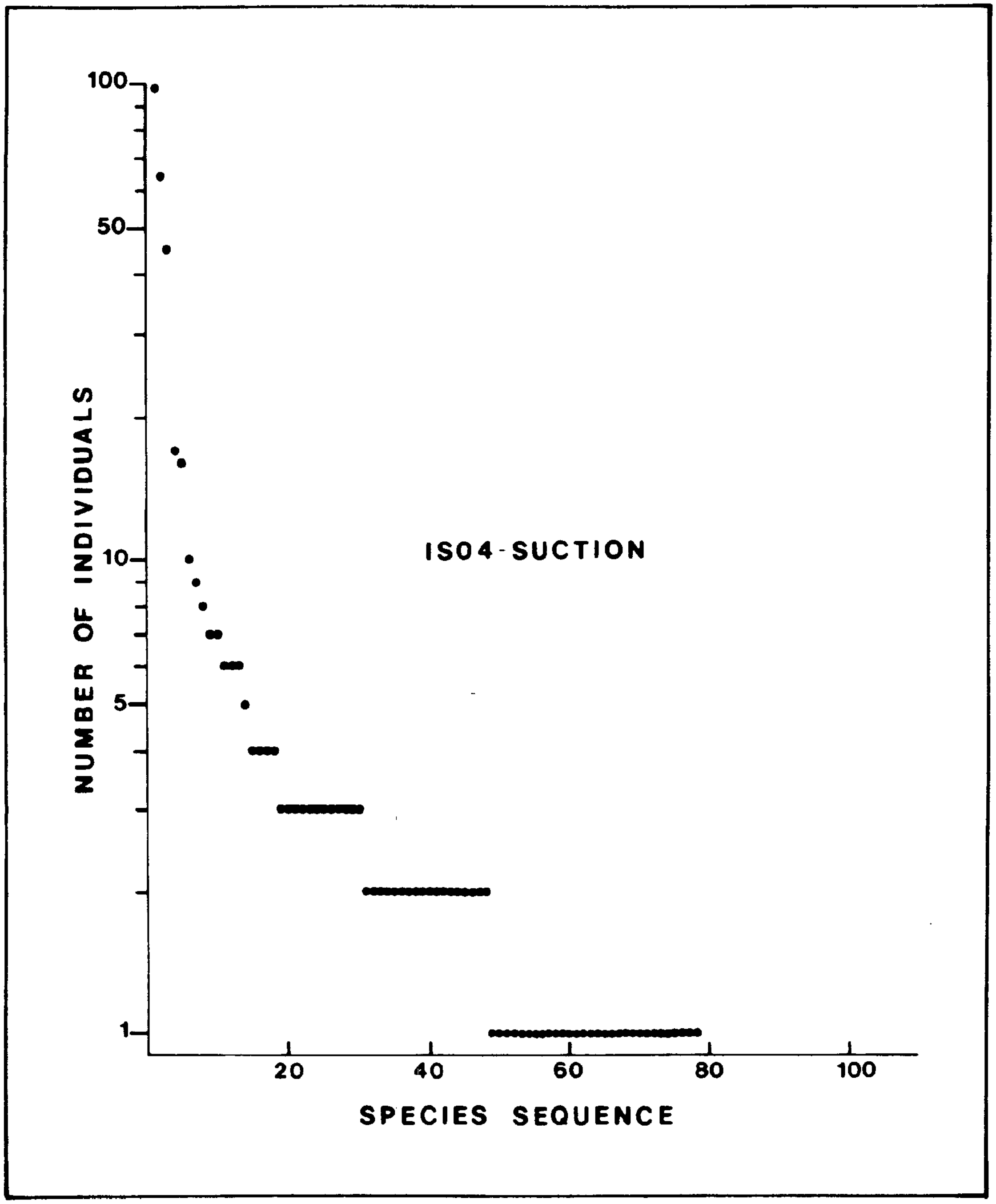

Figure 5.8. Dominance diversity curve computed for airlift suction collections at IS04. Only species counted rather than weighed in the collections were used to generate the curve. See Table 5.4 for ranked species list used in the generation of this curve.

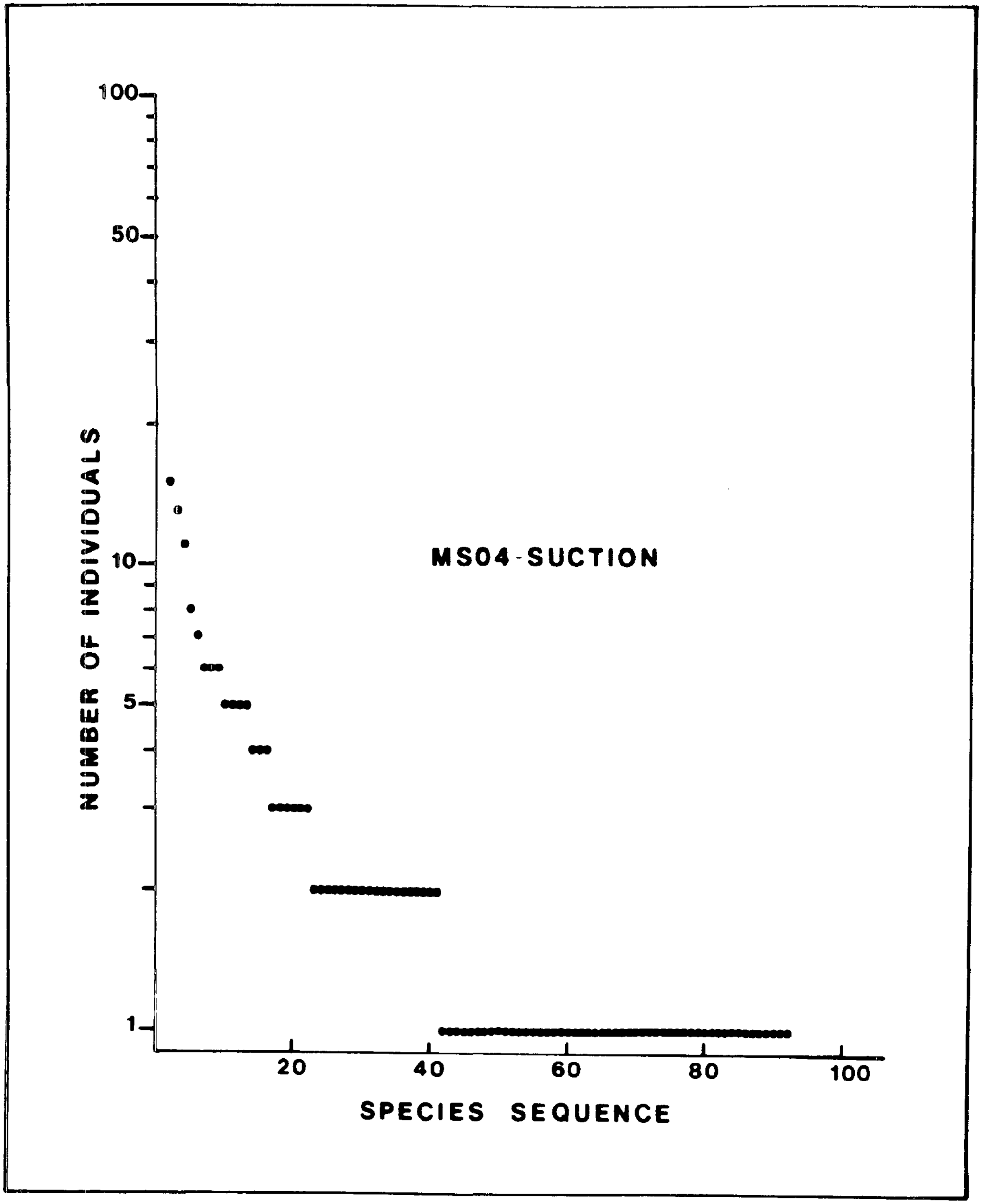

Figure 5.9. Dominance diversity curve computed for airlift suction collections at MS04. Only species counted rather than weighed in the collections were used to generate the curve. See Table 5.5 for ranked species list used in the generation of this curve.

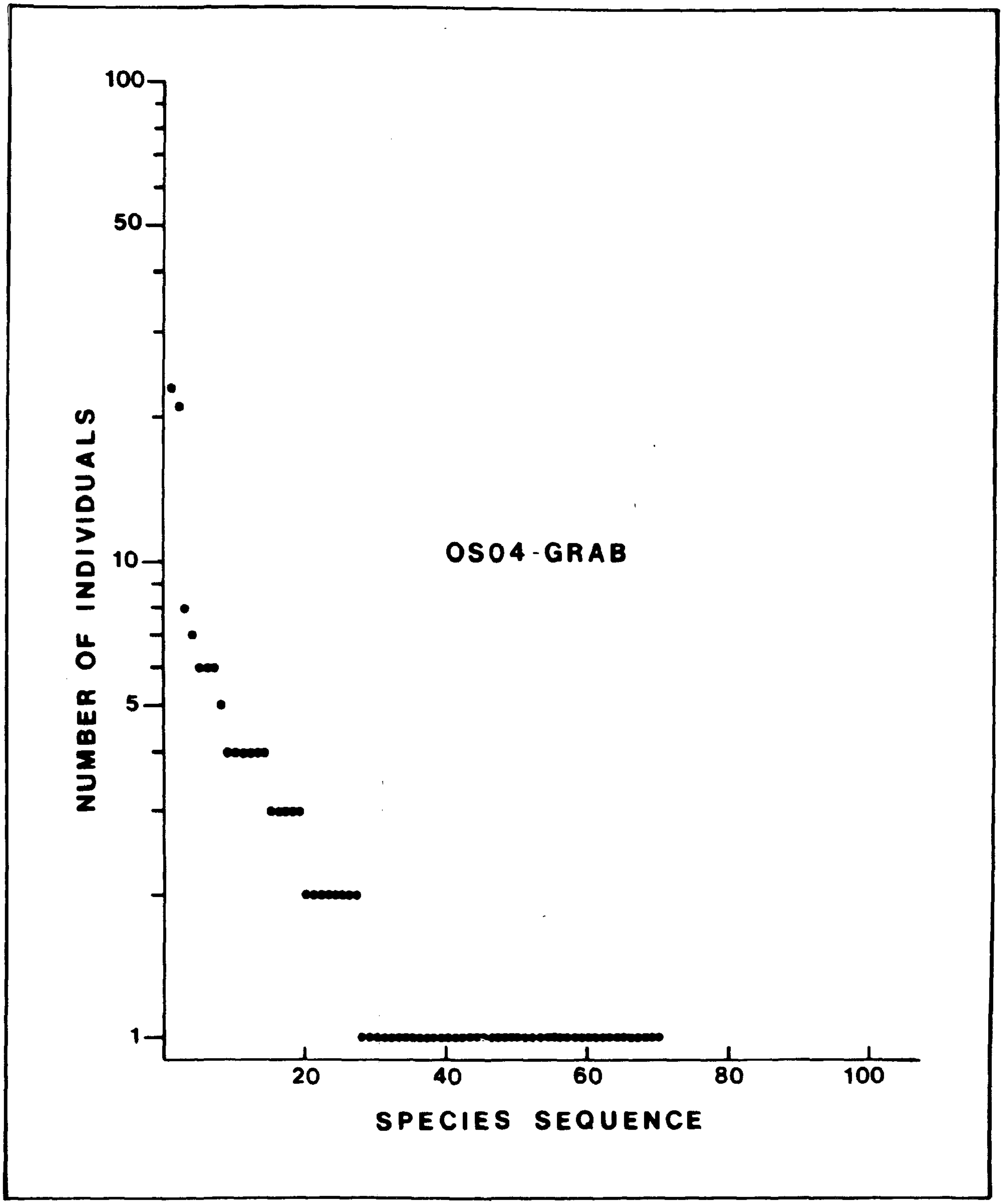

Figure 5.10. Dominance diversity curve computed for Smith-McIntyre grab collections at OS04. Only species counted rather than weighed in the collections were used to generate this figure. See Table 5.6 for ranked species list used in generating this curve.

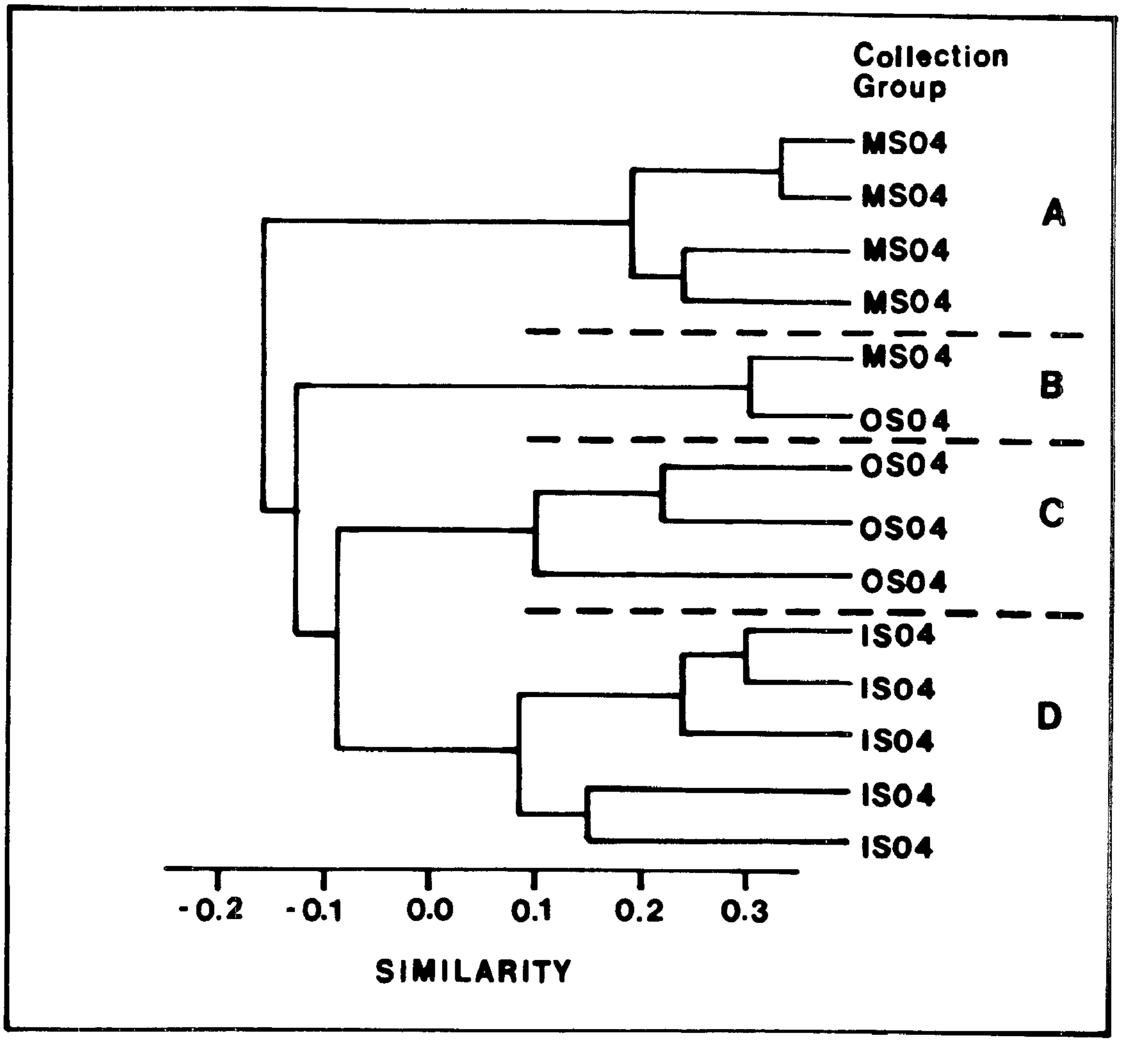

Figure 5.11. Collection associations delineated from normal (Canberra) cluster analysis of airlift suction and grab samples at IS04, MS04, and OS04. One collection from OS04 was deleted from the analysis due to low (one) species number.

were collected at both stations, resulting in a high similarity value of 0.30 between these collections.

Nineteen species groupings were delineated from the inverse (Canberra) cluster analysis (Table 5.12), with associations ranging from similarity values of 0.14 to 0.79. Those species which were tightly associated in Group A (0.79) were restricted to IS04; the species in Group P (0.54) were collected only at MS04. The weak association of species of Group O (0.14) was a reflection of low abundance but ubiquitous distribution. The large range in the level of association of these groups is a reflection, in many cases, of a strong association among species of restricted distribution and a weak relationship among species of low abundance, but wide distribution patterns.

Shown in Figure 5.12 are the results of nodal analysis which describes collections at a station in terms of characteristic species and species groups resulting from inverse cluster analysis in terms of patterns of occurrence in collections. Species of Group C showed very high constancy (> 0.70) at IS04 and much lower constancy at the other two sites. Groups Q and S had high constancy at MS04 and low constancy at IS04 and OS04. Only Group N had high constancy at OS04, although Groups I, J, and L had moderate values at that sight; all had low values at the other two stations. Few species associations were consistently found at all three study areas, reflecting in most cases rather limited distribution. Group J, which included Amphiuridae A, *Heterocrypta granulata*, and *Harmothoe aculeata*, was distributed fairly evenly at the three study areas; Group M had a similar but low level of constancy at the sites. Patterns of species fidelity were similar to those found for species constancy; that is, species associations showing high or moderate fidelity at one station had low fidelity at the other stations (Figure 5.12).

DISCUSSION

The results of this study are based on data obtained by both qualitative and quantitative sampling gear. The rock dredge, trawl, and TV transect were three qualitative sampling methods used. There was greater similarity between replicate dredge collections than among replicate invertebrate trawl collections at MS04, suggesting that samples taken with a dredge are more reliable for documenting invertebrate and algal species occurrence. Taking invertebrate and algal samples by trawl was most effective for supplementing species lists, primarily among organisms that were patchily distributed at each site.

Although analysis of TV transects revealed frequent occurrence of octocorallian species at OS04 (Figure 5.2), dredge samples taken at this station contained low abundance of Octocorallia (Figure 5.5). The discrepancy in data between sampling gears may be due to the difficulty in pulling the dredge evenly over the large boulders and ledges evidenced at OS04; that is, the dredge may skim over many of the octocorals. The low frequency of occurrence of Porifera at MS04 and OS04 noted in TV analysis (Figure 5.3) was supported by biomass estimates gathered from dredge collections (Figure 5.5). However, greater than 10% of the species collected at MS04 were sponges (Figure 5.4), suggesting that sponges occurring at MS04 are either small erect species or encrusting ones representing a low proportion of the biomass in dredge collections (Figure 5.5) and occupying fairly cryptic positions in the community (Figure 5.3). The dredge appears to be the most reliable method for qualitatively sampling epibenthic organisms; however, coincident use of the TV transect and trawl sampling methods supplements species lists by sampling large, patchily distributed invertebrates occurring in areas difficult to collect with a dredge.

Table 5.12 Species associations delineated from inverse (Canberra) cluster analysis of the airlift suction and grab samples (N = 14) taken during summer 1980. The level of association is given for each grouping. Only species that were counted rather than weighed are included in the groups. (Amph = Amphipoda; Arth = Arthopoda; Dec = Decapoda; Ech = Echinodermata; Iso = Isopoda; Mol = Mollusca; Pol = Polychaeta.)

Group A (0.79)

- Pseudomedaeus agassizii - Dec
- Dorvillea sociabilis - Pol
- Polydora plena - Pol

Group B (0.19)

- Gammaropsis sp. - Amph
- Lepidonotus variabilis - Pol
- Amphiuridae C - Ech
- Modiolus americanus - Mol

Group C (0.24)

- Anachis lafresnayi - Mol
- Hydroides uncinata - Pol
- Ophiothrix angulata - Ech
- Arbacia punctulata - Ech

Group D (0.17)

- Melita appendiculata - Amph
- Lembos smithi - Amph
- Erichthonius brasiliensis - Amph
- Sabellaria floridensis - Pol
- Pisania tincta - Mol

Group E (0.24)

- Micropanope sp. - Dec
- Pteria colymbus - Mol
- Chione grus - Mol
- Gouldia cerina - Mol

Group F (0.49)

- Nassarius albus - Mol
- Abra aequalis - Mol

Group G (0.42)

- Mitrella lunata - Mol
- Urosalpinx sp. A - Mol
- Nucula proxima - Mol

Group H (0.56)

- Eulalia sanguinea - Pol
- Syllis hyalina - Pol
- Hydroides sp. A - Pol

Group I (0.31)

- Glycera tesselata - Pol
- Glycera papillosa - Pol
- Pomatoceros americanus - Pol
- Platynereis dumerilii - Pol

Group J (0.44)

- Amphiuridae A - Ech
- Heterocrypta granulata - Dec
- Harmothoe aculeata - Pol

Group K (0.58)

- Vermicularia knorrii - Mol
- Protula tubularia - Pol

Group L (0.31)

- Corbula dietziana - Mol
- Phyllodoce sp. A - Pol
- Photis sp. - Amph
- Lumbrineris latreilli - Pol

Group M (0.33)

- Musculus lateralis - Mol
- Turbonilla sp. A - Mol

Group N (0.54)

- Onuphis nebulosa - Pol
- Travisia parva - Pol
- Prionospio sp. B - Pol

Table 5.12 (Continued)

Group O (0.14)

Liljeborgia sp. A - Amph
Mangelia rugirima - Mol
Unciola laminosa - Amph
Marphysa sp. - Pol
Tellina versicolor - Mol

Group P (0.55)

Mithrax sp. A - Dec
Tellina sp. - Mol
Lumbrineris inflata - Pol

Group Q (0.39)

Ampithoe sp. A - Amph
Ophiactis algicola - Ech
Erichsonella filiformis - Iso
Phyllocarida - Arth
Podocerus sp. - Amph

Group R (0.26)

Alpheus formosus - Dec
Nassarina glypta - Mol
Amphiodia pulchella - Ech
Sicyonia laevigata - Dec

Group S (0.26)

Ampelisca agassizi - Amph
Eunice vittata - Pol
Ophiostigma isacanthum - Ech
Hydroides crucigera - Pol
Lembos unicornis - Amph

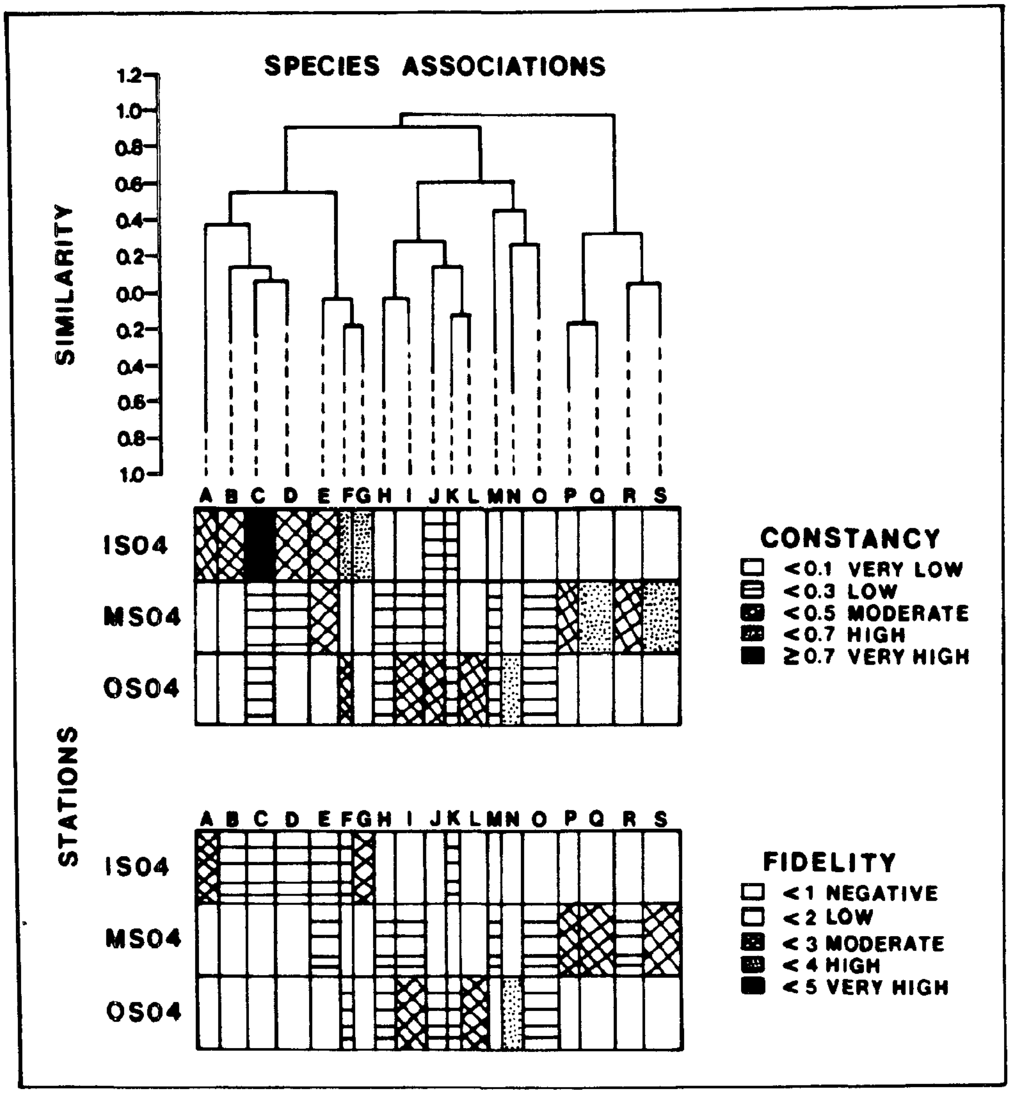

Figure 5.12. Nodal analysis of species associations delineated from the inverse (Canberra) cluster analysis of the suction and grab samples (N = 14) taken at IS04, MS04, and OS04. Levels of constancy and fidelity are given below the hierarchical structure of the dendrogram which was generated in the inverse cluster analysis. Dashed lines begin at the species group similarity index. Width of species groups is proportional to the number of species in the association.

The suction and grab samplers were two quantitative sampling methods used. In areas inaccessible for diver sampling with the suction sampler, remote collecting with the Smith-McIntyre grab was used. It is difficult to compare these two methods without concurrent use of both sampling devices at the same station. However, comparison of species lists of suction and grab samplers (Appendices 24-26) indicates that fewer species were collected at OS04 (using the Smith-McIntyre grab) than at IS04 and MS04 (using the suction sampler). This difference in number of species collected reflects the more depauperate fauna and flora at OS04 indicated by a comparison of dredge collections at the sites (Appendices 19-21); it also reflects the incapability of the grab sampler to remove all organisms from the rock substrata. Further, since the grab is a remote sampling device, it is more difficult to position the grab to collect samples from the rock substrata within the study area. Therefore, the suction sampler proved to be a more accurate and effective quantitative sampling device than the Smith-McIntyre grab.

Analysis of data from qualitative as well as quantitative gears indicates that MS04, the study area in the southern portion of Onslow Bay, has higher species diversity and greater invertebrate and algal biomass during the summer than either IS04 or OS04, which are located in more northerly waters (Table 5.11 and Appendix 23). Other studies have found increasing species richness in communities with decreasing latitude (Pianka 1966, Johnson et al. 1968, Emlen 1973) and attribute this diversity gradient along the geographic scale to increasing production (Connell and Orias 1964, Paine 1966, Pianka 1966) and habitat stability (Pianka 1966).

However, Thorson (1957) found that burrowing organisms (e.g., holothuroids, ophiuroids) did not show significant latitudinal trends in diversity, which contrasts with results reported for epifaunal organisms (Emlen 1973). Further, Hessler and Sanders (1967) and Sanders (1968) indicate that diversity of the soft sediment infauna in the deep sea is much greater than in equivalent shallow marine environments from temperate latitudes, being the same magnitude as that found in shallow marine tropics. They attribute the high diversity of the deep sea to great stability of the physical environment.

Paine (1966) could not find any relationship between latitude and diversity on the local scale and felt that diversity in hard bottom communities was related to the level of biological disturbance (predation) in the system. Other studies have indicated that local differences in species diversity in hard bottom communities are due to variations in physical disturbance, e.g., siltation and water turbidity (McCloskey 1970, Loya 1972, Preston and Preston 1975, Loya 1976). Although samples were not taken on a seasonal basis at the three areas in this study, perhaps increased physical disturbance, e.g., heavy sediment load and larger seasonal temperature fluctuations of the waters, has resulted in lower species diversity at IS04 and OS04. That is, possibly fewer species can tolerate the harsher environmental conditions prevalent at IS04 and OS04. Greater species richness of the majority of taxa at MS04 (Table 5.12) is due partly to the more benign conditions characteristic of the subtropical waters bathing this station.

That the seaweed species are an important constituent of the community in terms of diversity, abundance, and productivity at MS04 is evident from the data (Table 5.10 and Figure 5.5). In addition, higher species richness of the invertebrates at MS04 possibly is due to high diversity and abundance of algae which offer numerous microhabitats. The absence of most algae from IS04 and OS04 is undoubtedly due to reduced irradiance on the bottom, resulting from increased suspended sediments at IS04 and greater depth at OS04. Only a few species, mostly crustose coralline algae (Appendices 21 and 26) were collected at OS04. Since other studies have indicated that algal populations occurring in Onslow Bay show large seasonal fluctuations in biomass and percent cover (Schneider 1976, Peckol 1980), seasonal variation in species diversity and composition will undoubtedly be greater at MS04 than IS04 and OS04.

There was large variation among study areas regarding which taxonomic group dominated in terms of species number (Figure 5.4) and biomass (Figure 5.5). Pearse and Williams (1951) found that Decapoda, Polychaeta, and Porifera dominated in terms of species numbers in a reef system off the Carolinas comparable in depth to IS04. A similar pattern of dominance was evident for IS04 (Figure 5.4). Other studies of the submerged reef system off the coast of the Carolinas indicated that Decapoda (Cain 1972) and Mollusca (Menzies et al. 1966) were the dominant groups; Mollusca was the dominant group by weight (Figure 5.5) and Decapoda, Echinodermata, and Mollusca predominated by species number (Figure 5.4) at OS04. In contrast, data from a reef structure comparable to OS04 in northeastern Gulf of Mexico indicated that while Mollusca contributed 75% of the macrofauna, echinoderms were rare (Ludwick and Walton 1957).

A number of studies have used cluster analysis for identifying biogeographic discontinuities (Day et al. 1971, Field 1971, Hazel 1972, Hughes et al. 1972) among species groupings. All collections taken with the rock dredge (Figure 5.6) and most collections taken with airlift suction and grab samplers (Figure 5.11) clustered into groups corresponding to the study sites IS04, MS04, and OS04, reflecting geographical or bathymetric discontinuities of the areas. According to Cerame-Vivas and Gray (1966) and Environmental Research and Technology, Inc. (1979), IS04 and OS04 are within the area influenced by the Virginian Current (Virginian Province) while MS04 falls in the Carolinian Province (dominated by tropical and subtropical species). Since collections taken at IS04 and OS04 are fairly dissimilar, obviously there are both inshore and offshore species characteristic of the Virginia Province, suggesting bathymetric zonation.

According to the normal cluster analysis of the dredge collections (Figure 5.6) IS04 and MS04 were more similar to one another than to OS04, while cluster analysis of suction and grab collections (Figure 5.11) suggested that IS04 and OS04 were more closely related to each other than to MS04. This discrepancy is undoubtedly a result of deleting colonial forms and algae from suction and grab cluster analysis (while including them in the dredge cluster analysis) and deleting some of the arthropod groups from the dredge cluster analysis (see Methods).

Many species associations delineated in the inverse (Jaccard and Canberra) cluster analyses were collected at only one of the study areas, e.g., Groups E and G (Figure 5.7) and Groups A and N (Figure 5.12) in the cluster analysis of the dredge collections and suction and grab collections, respectively, reflecting either geographic or bathymetric restriction of many species. Few species were collected at all three study areas, e.g., *Amphiodia pulchella*, *Synalpheus townsendi*, *Ophiothrix angulata*, Amphiuridae C, and *Nassarius albus*.

Due to the geographical restriction of most species, dominance in one or a few species was limited to a single study area. Dominance (in terms of biomass) was shared by a few algal species at MS04 (Table 5.10) while *Melita appendiculata* and *Prionospio* sp. B were the numerically dominant species at IS04 and OS04, respectively (Table 5.9). Although different species dominated at each of the study areas, the shape of the dominance diversity curves (Figures 5.8 - 5.10) indicated that resource space is divided in a similar manner at the three study areas. However, the shapes of the curves, which were similar to curves obtained from South Carolina data (Volume I), do not follow any of the models derived to explain dominance diversity relationships (Whittaker 1965, 1970). Perhaps the exclusion of colonial organisms and algae is one reason for this. There is no good method, however, of assigning importance values on all organisms from live bottom communities, since so little is known about the community dynamics.

A number of studies have indicated the importance of sediment type in the control of the distribution of benthic fauna in soft sediments (Wieser 1959, Rowe and Menzies 1969, Nichols 1970, Day et al. 1971, Field 1971, Hughes et al. 1972, Boesch 1973). Marked changes in the sediment size distribution, related to the movements and proximity of the Gulf Stream, were found to result in restricted distribution of the invertebrates (Rowe and Menzies 1969). Other factors found important in the control of soft sediment infauna distribution and composition include availability of organic material (Day et al. 1971, Hughes et al. 1972), presence or absence of other species (Hughes et al. 1972), and seasonal fluctuations of environmental conditions (Hedgpeth 1953, Haedrich et al. 1975).

However, Day et al. (1971), in contrast with Cerame-Vivas and Gray (1966), did not find any obvious differences between the inshore and offshore stations and felt that the infauna characteristic of the outer part of the continental shelf of North Carolina was not part of the tropical Caribbean Province. In a later study, Field (1971) suggested that the distributional patterns of infauna across the North Carolina shelf (Day et al. 1971) were due to uniform sediment composition resulting from strong bottom currents which inhibit deposition of fine sediments and organic matter. Similarly, as suggested in this study, differences in species abundance and diversity in live bottom assemblages are partially a reflection of direct or indirect effect of physical disturbance.

IMPACT/ENHANCEMENT

The major impact of hydrocarbon exploration on epibenthic communities is expected to be the burial of those communities in the vicinity of drilling operations, converting epibenthic communities into soft bottom communities. In addition, suspended particulate matter in the water column (from drilling muds) may cause inhibition of feeding activities of suspension feeding invertebrates, thus extending the area of impact some distance from the drilling operations. The live bottom areas in Onslow Bay would be more influenced than those in other areas because the communities in Onslow Bay develop in a system which normally experiences very little sedimentation (particularly of fine sediments). Algae could be affected by the lower light penetration in areas influenced by suspended drilling muds. Dissolved hydrocarbons, organic compounds and metals from the produced waters could be incorporated into the tissues of the epibenthic organisms leading to higher levels of these substances as they are passed through the food chains. The inshore station (IS04) would probably be least affected by drilling activities since it is located in an area of considerable naturally occurring suspended sediments. In the vicinity of the Gulf Stream where materials would be carried away from the drilling activities, there would be either a wider area of effect or, when rapid dilution to near background levels occurred, little or no effect on epibenthic communities.

Enhancement of epibenthic communities would occur in the form of increased abundance due to increased surface area of hard substrate provided by the physical structure of a drilling platform. Because of the extension of the new hard substrate from surface to bottom, the diversity of organisms might be increased locally, particularly among algae in the shallower depths where light penetration is good.

CONCLUSIONS

The epibenthic communities found on live bottoms off the coast of North Carolina are highly variable and appear to depend as much on hydrography and rock formation as on depth. Since colonial forms and algae were excluded from some of the analyses (i.e., data from suction and grab samples), similarities and differences among the three areas sampled are particularly difficult to quantify. The diversity of these communities is high, especially when compared with shallow water, temperate zone communities. The large number of tropical and subtropical species leads to the conclusion that these areas represent a northward extension of a Caribbean biogeographic province.

The inner shelf station (IS04) is probably subject to greater physical stress than the other two stations because of its location in shallow water north of Cape Hatteras. The middle shelf station (MS04) had the highest diversity and greatest invertebrate and algal biomass of the three sites investigated. Although not documented here, the algae undoubtedly undergo great seasonal fluctuations in diversity and biomass at MS04. The outer shelf station (OS04) is located in an area which may experience strong temperature fluctuations as cool waters of the Virginian Current oscillate and are replaced by the warmer waters of the Gulf Stream.

CHAPTER 6

NEKTONIC COMMUNITY

INTRODUCTION

Species composition and economic value of the nektonic community associated with live bottoms in the South Atlantic Bight are well known (Struhsaker 1969, Huntsman 1976, Ulrich et al. 1977, Powles and Barans 1980). Because of the complexity of reef ecosystems, however, important information about fish production, diversity, and community composition is not well known at present. The main goals of the nektonic community analysis were to determine species composition; calculate estimates of species abundance, biomass, and diversity; analyze species assemblages to distinguish similarities among groups of fishes and their distribution patterns; and discuss potential impacts and enhancements of drilling activities on the nektonic communities associated with live bottom habitats off North Carolina.

METHODS

Laboratory Analysis:

Trawl Collections - All fishes which were not identified in the field were returned to the laboratory for positive identification. Representative specimens of most species were preserved in 10% formalin, then transferred to 50% isopropanol.

Underwater Television Transects - The television tapes from MS04 and OS04 were divided into three 20-min segments for a total of 60 min per station and, for comparison with other gear types, attempts were made to identify all fish species seen. Although identification to the species level proved to be impossible for most of the fish viewed, families and species of reef fish were identified whenever possible. The alternative technique of analysis used was to count and record by category (demersal or pelagic) all fishes visible on the television screen during each 10-sec interval. This process was repeated by a second observer and the two observations were combined to obtain an average number of demersal and pelagic fish per station.

Diver Observations - Data recorded by divers on fish observation transects at IS04 and MS04 (see Chapter 2 for collection method) were tabulated for comparison with trawl and television sampling techniques. Abundance of fishes was calculated on a number-per-minute as well as a number-per-kilometre basis.

Baited Fishing Gear - Rod and reel, vertical longlines, and Antillean traps were deployed to catch large, predatory fishes that were captured infrequently by trawl. Abundance and catch-per-effort values were calculated for each gear type, and selected priority species sampled were analyzed for food habit information (Chapter 7).

Data Analysis:

Abundance - Abundance of the ten most important demersal teleosts caught in trawls at IS04 and MS04 was estimated by calculating the percent occurrence by number. An index of relative abundance (Musick and McEachran 1972) was also calculated for each species and for total demersal teleosts at each station:

$$\text{Index of Relative Abundance} = 1/n \sum_{1}^{n} \log_e(x + 1)$$

where n = number of trawls at a station and x = number of individuals of each species in a tow.

Biomass - Biomass estimates were obtained from trawl efforts for (1) all trawl caught nekton (fishes and squid) and (2) demersal teleosts only. Untransformed as well as transformed ($\log_e[x + 1]$) mean catches per tow were calculated because trawl catches are not normally distributed (Taylor 1953). The mean catch per tow of the transformed values from IS04 and MS04 was estimated by following the methodology of Bliss (1967):

$$E\,(\bar{y}_h) = \exp(\bar{y}_h + S_h^2/2) - 1$$

where $E(\bar{y}_h)$ = estimated mean catch per tow and $\bar{y}_h$ and S_h^2 are the study site mean and variance expressed in logarithmic units. Biomass per unit area was obtained by dividing the untransformed mean catch per tow by the mean area swept by the trawl (in hectares). The mean area covered by the trawl ($\bar{a}$) was estimated by the following equation modified from Klima (1976):

$$\bar{a} = \frac{D \times (0.6H)}{10{,}000\ m^2\ ha^{-1}}$$

where H = headrope length (m) and D = mean distance trawled (m). The constant 0.6 designates an effective horizontal trawl opening of 60% of the headrope length (Wathne 1959).

Dominance and Diversity - The degree of dominance in the fish community at each station was estimated by a dominance index (McNaughton 1967):

$$D.I. = \frac{n_1 + n_2}{N} \times 100$$

where n_1 and n_2 are the first and second most abundant species (by number) and N = total number of individuals. Dominance was also described according to the dominance diversity curve method reported by Whittaker (1965).

Estimates of species diversity (H'), richness, and evenness (J') were calculated according to Pielou (1975) for each trawl at IS04 and MS04 (Appendix 27). In addition, estimates of H', J', and species richness were calculated for (1) all trawl samples pooled by station and (2) trawl samples pooled by light phase within a station.

Cluster Analysis - Cluster analysis was used to determine the similarities between trawl collections and to compare the similarities among species assemblages. Only fish species caught in at least two trawl samples were ranked by occurrence. The clustering technique involved a fusion of paired groups of similar entities into larger groups until the complete data set was utilized (Boesch 1977). A flexible sorting method was used with a cluster intensity coefficient (β) of -0.25 (Lance and Williams 1967). The similarity coefficient used to analyze trawl data was described by Bray and Curtis (1957). Normal classification clustered trawl collections as entities, while inverse classification pertained to the clustering of fish species (Williams and Lambert 1961b).

RESULTS

Quantitative Assessment of Fish Captured by Trawl:

Species Composition and Abundance - A total of 8342 fish species representing 27 families and 53 species were collected from all trawl samples. Of the 8342 fish sampled, 1570 were pelagic species, mostly from the families Engraulidae and Stromateidae (Appendix 28). The remaining 6772 fish, representing 80.5% of the total number of demersal fish sampled, were comprised mostly of three species, *Stenotomus aculeatus* (3160 individuals), *Micropogonias undulatus* (1314), and *Leiostomus xanthurus* (978). Other abundant species found were *Monacanthus hispidus* (681), *Apogon pseudomaculatus* (195), *Haemulon aurolineatum* (145), *Equetus umbrosus* (69), *Diplodus holbrooki* (50), *Priacanthus arenatus* (24), and *Haemulon plumieri* (19) (Table 6.1).

At IS04, 24 species of fish from 16 families were collected. Approximately 27% (1553) of the 5670 specimens caught were pelagic species such as stromateids, engraulids, pomatomids, clupeids, and the sciaenid *Cynoscion regalis* (Appendix 28). Demersal fish abundance was dominated by three species: *Stenotomus aculeatus* (1799), *Micropogonias undulatus* (1314), and *Leiostomus xanthurus* (978) (Table 6.2). Demersal fish abundance was more than three times greater at night than during the day, and the number of species collected at night was more than twice that taken in day trawls (Table 6.3). Indices of abundance for each of the three most abundant species were an order of magnitude greater than most of the other indices calculated at IS04 (Table 6.2). The overall index of relative abundance for demersal fish at IS04 was 6.29.

Trawl collections of fish at MS04 consisted of 2672 individuals representing 21 families and 35 species (Appendix 28). Pelagic species (carangids and clupeids) comprised only 1.6% of the total number of fish collected. *Stenotomus aculeatus* (1361 individuals) was the dominant species by number, followed by *Monacanthus hispidus* (681), *Apogon pseudomaculatus* (195), and *Haemulon aurolineatum* (145). These four species accounted for 90.6% of the total number of demersal fish collected (Table 6.2). Day trawls yielded only about one-third the number of fish found in night trawls (Table 6.4). Indices of abundance for the ten dominant species at MS04 ranged from 0.94 to 4.48 (Table 6.2), as opposed to an index value of 5.39 for all demersal fish at MS04.

Biomass - Biomass estimates at IS04 are given in Table 6.5. Untransformed mean catch per tow values for both total nekton and demersal teleosts varied less than 2.0 kg from estimated mean catches per tow. Total nekton biomass was 80.758 kg ha^{-1}, compared to 62.181 kg ha^{-1} for demersal teleosts. Differences between total nekton and demersal teleost biomass values are principally explained by the presence of the pelagic fish, *Peprilus triacanthus*, which occurred in most of the trawls at IS04.

Mean biomass per tow calculations of untransformed and estimated transformed data from total nekton catches at MS04 differed by 1.80 kg per tow, as opposed to a difference of 0.73 kg per tow for demersal teleosts (Table 6.4). Total nekton biomass values were greatly influenced by one specimen (*Dasyatis*

Table 6.1 Ten most abundant demersal fish species caught by trawl, all stations combined. n = number of occurrences in 12 trawls.

Species	Total Number	Percent of Total	n
Stenotomus aculeatus	3160	46.7	12
Micropogonias undulatus	1314	19.4	6
Leiostomus xanthurus	978	14.4	6
Monacanthus hispidus	681	10.1	6
Apogon pseudomaculatus	195	2.9	3
Haemulon aurolineatum	145	2.1	3
Equetus umbrosus	69	1.0	3
Diplodus holbrooki	50	0.7	3
Priacanthus arenatus	24	0.4	6
Haemulon plumieri	19	0.3	4
Totals	6635	98.0	

Table 6.2 Rank by number of dominant fishes caught by trawl off North Carolina during summer 1980 sampling.

STATION IS04

Species	Number	Percent of Total	Index of Relative Abundance
Stenotomus aculeatus	1799	43.75	5.03
Micropogonias undulatus	1314	31.96	4.87
Leiostomus xanthurus	978	23.78	4.98
Menticirrhus americanus	5	0.12	0.53
Synodus foetens	5	0.12	0.46
Priacanthus arenatus	5	0.12	0.41
Prionotus carolinus	2	0.05	0.18
Paralichthys dentatus	2	0.05	0.23
Symphurus plagiusa	1	0.02	0.12
Sphoeroides dorsalis	1	0.02	0.12

STATION MS04

Species	Number	Percent of Total	Index of Relative Abundance
Stenotomus aculeatus	1361	51.79	4.48
Monacanthus hispidus	681	25.91	3.49
Apogon pseudomaculatus	195	7.42	2.50
Haemulon aurolineatum	145	5.52	2.30
Equetus umbrosus	69	2.62	1.79
Diplodus holbrooki	50	1.90	1.69
Haemulon plumieri	19	0.72	1.06
Priacanthus arenatus	19	0.72	0.99
Centropristis striata	16	0.61	1.05
Calamus leucosteus	13	0.49	0.94

Table 6.3 Ranking of ten most abundant demersal teleosts caught by trawl at IS04, by light phase

Species	Total Number by Day	Percent of Total
Leiostomus xanthurus	511	55.3
Micropogonias undulatus	233	25.2
Stenotomus aculeatus	178	19.3
Menticirrhus americanus	1	0.1
Larimus fasciatus	1	0.1
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-

Species	Total Number by Night	Percent of Total
Stenotomus aculeatus	1621	50.8
Micropogonias undulatus	1081	33.9
Leiostomus xanthurus	467	14.6
Priacanthus arenatus	5	0.2
Synodus foetens	5	0.2
Menticirrhus americanus	4	0.1
Paralichthys dentatus	2	0.1
Prionotus carolinus	2	0.1
Centropristis striata	1	< 0.1
Sphoeroides dorsalis	1	< 0.1

Table 6.4 Ranking of ten most abundant demersal teleosts caught by trawl at MS04, by light phase.

Species	Total Number by Day	Percent of Total
Stenotomus aculeatus	612	91.2
Priacanthus arenatus	15	2.2
Calamus leucosteus	10	1.5
Monacanthus hispidus	10	1.5
Aluterus schoepfi	6	0.9
Serranus phoebe	4	0.6
Centropristis striata	3	0.4
Pagrus pagrus	2	0.3
Centropristis ocyurus	1	0.1
Haemulon plumieri	1	0.1

Species	Total Number by Night	Percent of Total
Stenotomus aculeatus	749	38.3
Monacanthus hispidus	671	34.3
Apogon pseudomaculatus	195	10.0
Haemulon aurolineatum	145	7.4
Equetus umbrosus	69	3.5
Diplodus holbrooki	50	2.6
Haemulon plumieri	18	0.9
Centropristis striata	13	0.7
Ophidion holbrooki	11	0.6
Centropristis ocyurus	7	0.4

Table 6.5 Biomass estimates for (1) all trawl-caught fish (including squid) and (2) demersal fishes only at North Carolina inner and middle shelf stations for summer 1980.

	Mean catch (kg) per tow untransformed	Mean catch (kg) per tow transformed	Estimated mean catch (kg)/tow retransformed	Biomass (kg/ha)
Station IS04				
Total fish	49.505	3.785	50.780	80.758
Demersal	38.117	3.431	39.895	62.181
Station MS04				
Total fish	47.50	3.607	49.300	58.354
Demersal	28.683	3.299	29.417	35.237

centroura) that weighed 110.70 kg and accounted for most of the difference between demersal teleost and total nekton biomass calculations. Biomass estimates for total nekton and demersal teleosts were lower at MS04 than at IS04.

Diversity and Dominance - Diversity calculations varied within station as well as between stations (individual diversity values for each trawl effort are presented in Appendix 27). At IS04, the diversities (H') calculated for day and night trawl collections were essentially equal (Table 6.6), even though night trawls had more than three times the number of individuals and twice the number of species. As a result, species richness was much greater at night than during the day. In contrast, diversity at MS04 was much higher for night collections than for day collections. The relatively low H' for day trawls can be attributed more to low evenness than to species richness. Species richness at night was only 50% higher than that calculated for the day, while evenness at night was about three times that for day trawls.

Day trawls at IS04 yielded a greater H' than MS04 day trawls, even though species richness at MS04 was three times that found at IS04. Species richness, H', and J' for MS04 night collections were all greater than those calculated for IS04 night trawls. In addition, overall diversity estimates at MS04 exceeded those calculated from IS04 trawls.

The dominance diversity curves for IS04 and MS04 did not resemble any of the curves described by Whittaker (1965), but it was evident that each station was dominated by two or three species (Figure 6.1). MS04 also had many more intermediate species than IS04. Dominance indices calculated at the two stations were very similar (Figure 6.1).

Cluster Analysis - As a result of cluster analysis, fish species caught in two or more trawls at either sample site clustered into six groups (Figure 6.2). The species included in each group are listed in Table 6.7.

Group 1 consisted of five species primarily associated with live bottom habitats. These species were among the six most abundant species sampled at night at MS04. Group 2 was composed of four species, two of which were designated priority species, Centropristis striata and Haemulon plumieri. Group 3 fish consisted of species which are allied more closely to live bottom areas than sand bottom areas. With the exception of Stenotomus aculeatus, which occurred at IS04 and MS04, the species which made up Groups 4 and 5 were restricted to IS04. As expected, these two groups of fish clustered apart from Groups 1, 2, and 3.

Analyzed trawl data indicated night trawls at MS04 had a very high similarity value, as did two of the three day trawls (Figure 6.3). The final day trawl did not cluster with the first two due to sampling error. It is possible that the trawl was off the bottom on this final tow (as evidenced by species caught). Normal analysis of MS04 trawls suggested a day/night difference in demersal fish composition. The higher intragroup similarity in Group C (IS04) indicated that species composition did not undergo as great a day/night change at IS04 as at MS04.

Fishes Observed or Collected by Other Gear:

Underwater Television - Analysis of underwater television was accomplished only at MS04 and OS04 because of poor visibility at IS04. Families of fishes identified from MS04 included Carangidae, Labridae, Pomacentridae, Sciaenidae, and Serranidae. Individual species seen were Equetus umbrosus, Hemipteronotus

Table 6.6 Species diversity (H'), species evenness (J'), and species richness for demersal fishes based on pooled replicate trawl collections, by station and light phase for summer, 1980.

Station	Number of Individuals	Number of Species	H'	J'	Species Richness
IS04					
Day	924	5	1.45	0.62	0.59
Night	3192	12	1.50	0.42	1.36
Total	4116	13	1.60	0.43	1.44
MS04					
Day	671	13	0.65	0.18	1.85
Night	1956	21	2.28	0.52	2.64
Total	2627	27	2.12	0.45	3.30

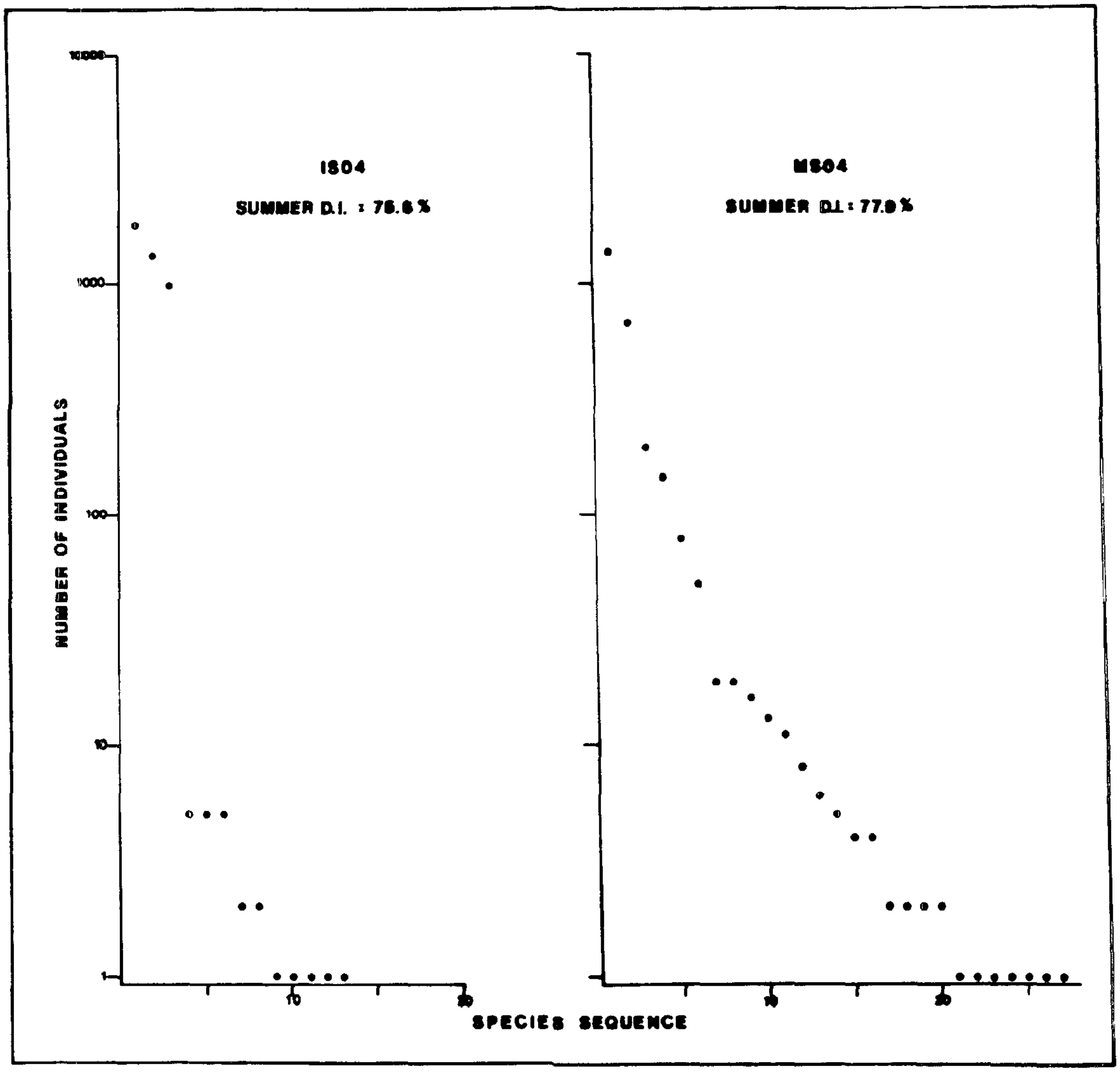

Figure 6.1. Dominance diversity curves and dominance index (D.I.) values for demersal fishes collected at inner and middle shelf stations.

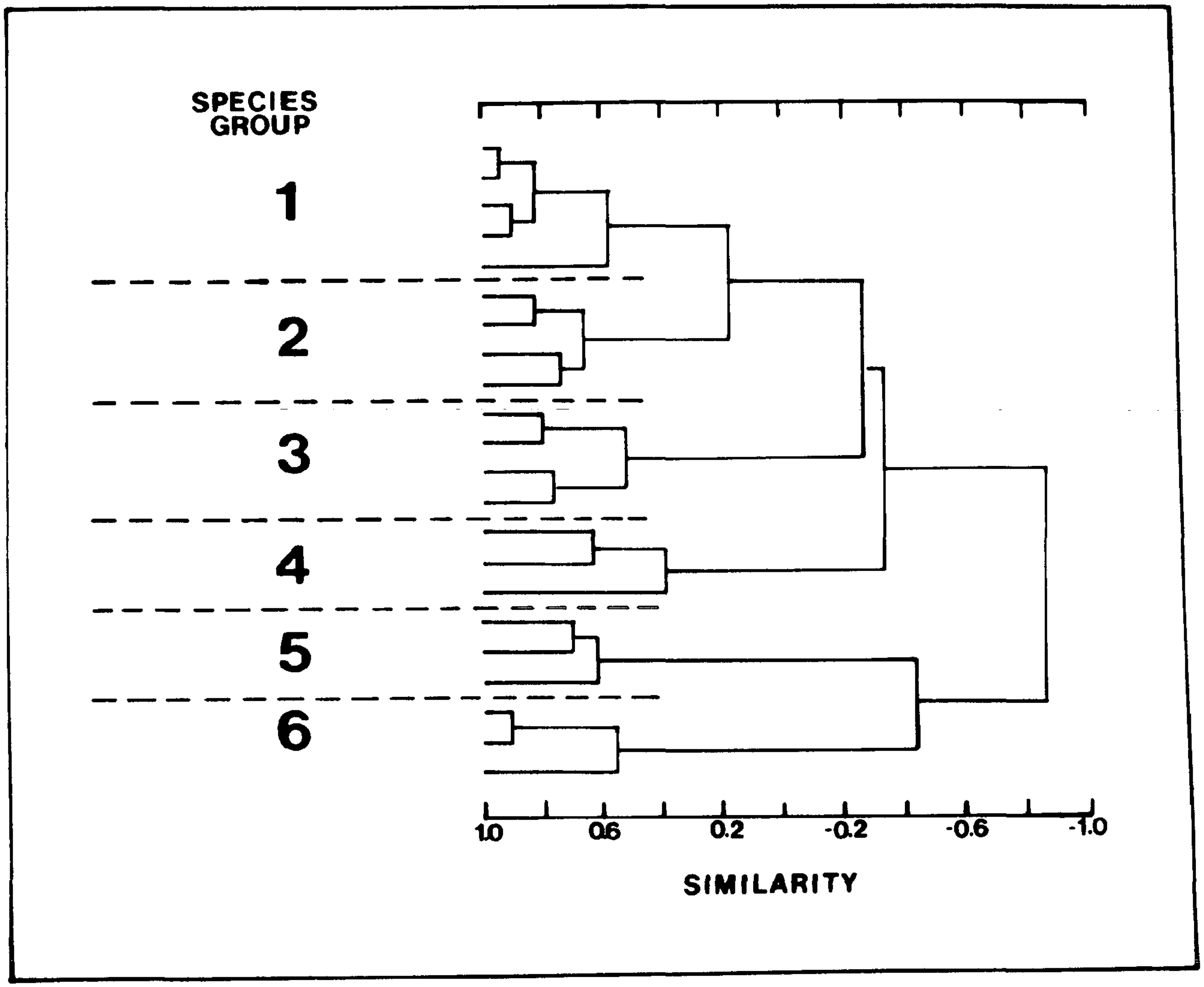

Figure 6.2. Species cluster (inverse analysis) for demersal fish species caught by trawl collections at IS04 and MS04 combined.

Table 6.7 Species associations derived from Bray-Curtis inverse cluster analysis of trawl samples (N = 12) for summer, 1980.

Group 1

Diplodus holbrooki
Paraques umbrosus
Apogon pseudomaculatus
Haemulon aurolineatum
Monacanthus hispidus

Group 2

Haemulon plumieri
Ophidion holbrooki
Centropristis striata
Centropristis ocyurus

Group 3

Equetus lanceolatus
Raja eglanteria
Prionotus carolinus
Porichthys plectrodon

Group 4

Priacanthus arenatus
Calamus leucosteus
Serranus phoebe

Group 5

Synodus foetens
Menticirrhus americanus
Paralichthys dentatus

Group 6

Leiostomus xanthurus
Micropogonias undulatus
Stenotomus aculeatus

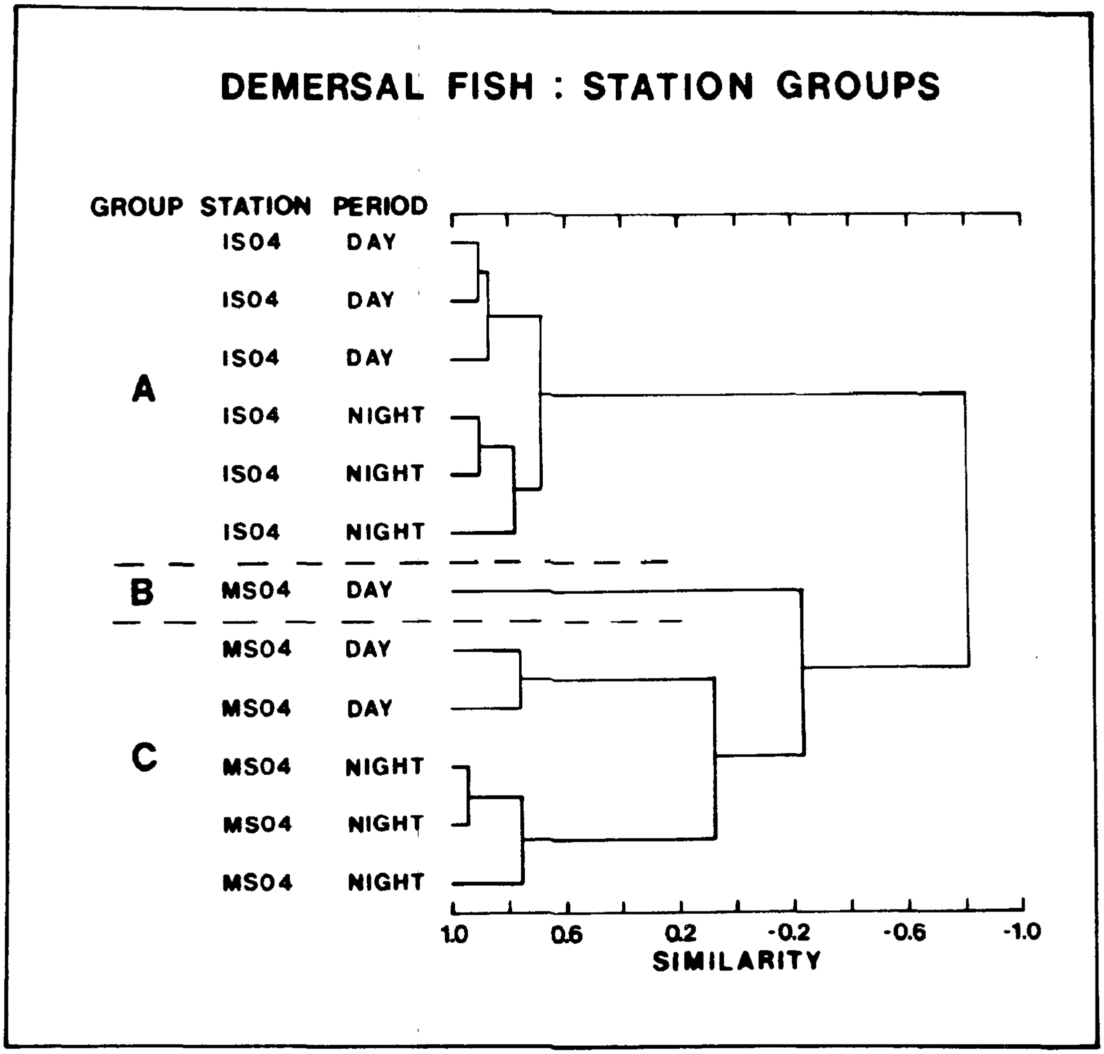

Figure 6.3. Normal cluster analysis of demersal fishes collected by trawl at inner and middle shelf stations.

novacula, and Seriola dumerili. Fifty-three demersal and 798 pelagic fishes were counted in the television analysis. Nine fish families were identified from television tapes at OS04: Apogonidae, Carangidae, Carcharhinidae, Labridae, Pomacentridae, Priacanthidae, Sciaenidae, Serranidae, and Sparidae. Five species were also noted: Apogon pseudomaculatus, Equetus umbrosus, Hemipteronotus novacula, Priacanthus arenatus, and Seriola dumerili. Counted in the television tapes at OS04 were 335 demersal and 196 pelagic fishes.

Catch data from trawling, television, and dive transects at MS04 were analyzed to compare results (Figure 6.4). Trawling produced the largest number of demersal fish per hour of effort. Divers enumerated the greatest number of demersal fish per kilometre. Television transects yielded the lowest number of demersal fish and the highest number of pelagic fish per hour as well as per kilometre. MS04 was the only station analyzed in this manner because it was the only station where all three techniques were employed.

Diver Observations - Five species of demersal fishes representing four families were observed at IS04: Centropristis striata (Serranidae), Diplodus holbrooki (Sparidae), Holacanthus bermudensis (Pomacanthidae), Opsanus sp. (Batrachoididae), and Stenotomus chrysops (Sparidae). A single blenniid was observed, but pelagic fishes were not sighted. No fishes were collected by divers at this station (Table 6.8).

At MS04, the fish transect yielded 34 species of fishes representing 16 families (Table 6.8). Demersal fishes accounted for 91% of the total species sighted. Pelagic species made up 9% or only three species. Four priority species were observed: black sea bass (Centropristis striata), gag (Mycteroperca microlepis), scamp (Mycteroperca phenax), and red porgy (Pagrus pagrus). A dominant non-priority species, white grunt (Haemulon plumieri), was the most abundant. Twenty-seven individuals with total lengths ranging between an estimated 20 - 30 cm were sighted. The greatest diversity of fishes, although not calculated, appeared to be over the margin of the ledge and to a lesser extent along the ledge face.

Baited Fishing Gear - Vertical longlines collected 30 fish representing seven species (Table 6.9). Centropristis striata was the most abundant species captured, and MS04 yielded the highest catch per effort (number per hour).

Hook and line efforts were more effective in collecting fish than longlines. Sixty-eight individuals (seven species) were collected, most of which were priority species such as Centropristis striata, Haemulon plumieri and Pagrus pagrus (Table 6.10). OS04 yielded the highest catch per effort with 23.6 individuals caught per hour.

Antillean traps caught 37 individuals. The two most abundant species collected by this method were C. striata and Stenotomus aculeatus. The greatest success, in terms of catch per effort, occurred at IS04 where 5.0 fish were sampled per hour of effort (Table 6.11).

Among all gear types used to collect demersal fishes, trawling was by far the most successful. Trawl efforts caught more demersal fish per hour, by weight as well as by number, than all other baited gear types combined (Table 6.12).

DISCUSSION

Species composition at IS04 was dominated in number and weight by sand bottom demersal species representative of the offshore winter trawl fishery off

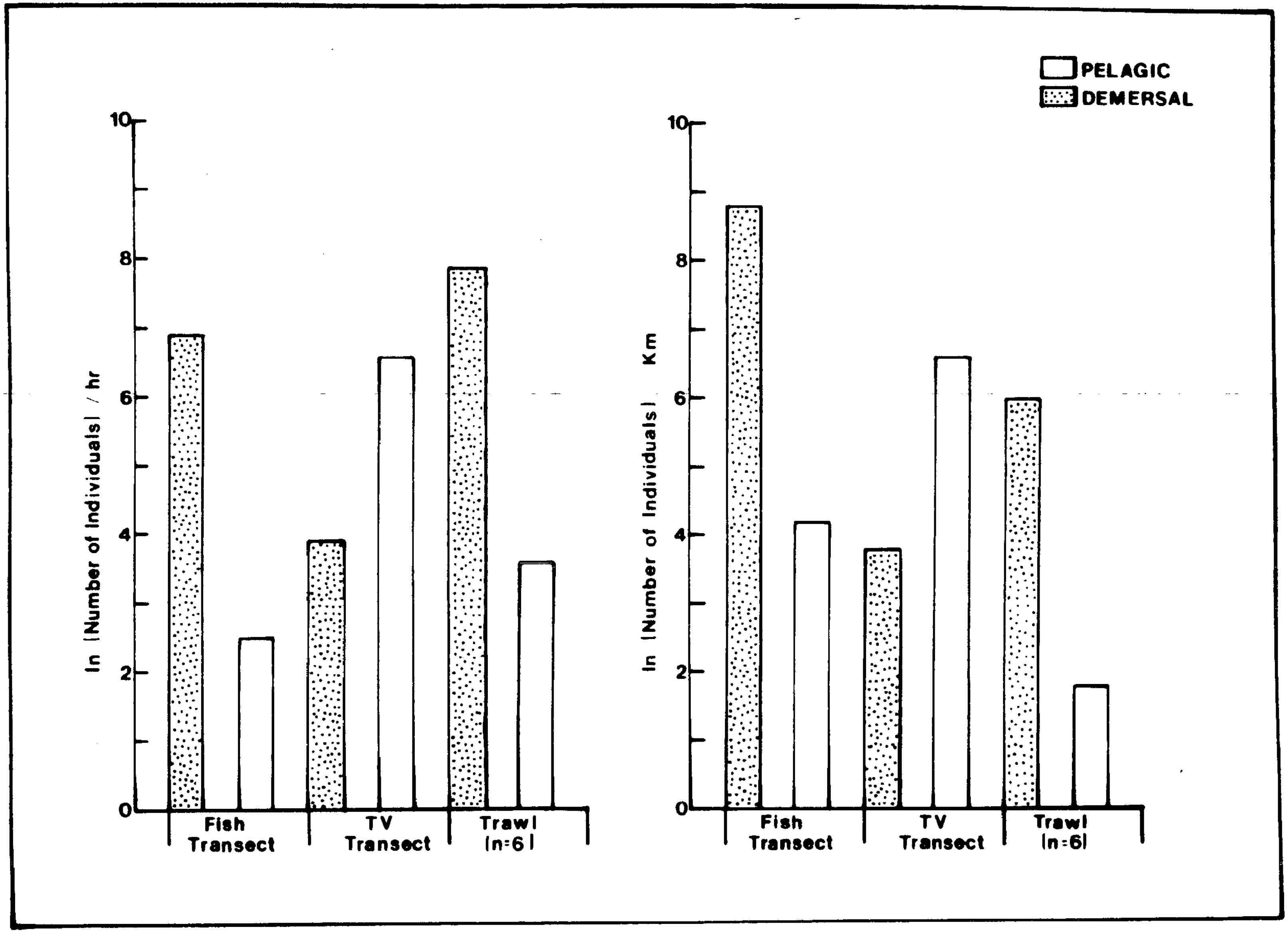

Figure 6.4. Relative abundance (by number) of pelagic and demersal fishes collected or observed by diver fish transects, television transects, and trawl at MS04.

Table 6.8 Fishes observed and collected from dive operations off North Carolina at inner and middle shelf stations for summer 1980. S = sighted; C = collected.

Family	Species	IS04	MS04
Carcharhinidae	Carcharhinus falciformis	-	1 S
Gadidae	Urophycis earlli	-	1 S
Batrachoididae	Opsanus sp.	1 S	1 S
Serranidae	Centropristis striata	2 S	12 S
	Centropristis ocyurus	-	1 S
	Liopropoma eukrines	-	1 C
	Mycteroperca microlepis	-	5 S
	Mycteroperca phenax	-	2 S
	Serranus subligarius	-	30 S
Grammistidae	Rypticus maculatus	-	1 S
Apogonidae	Apogon pseudomaculatus	-	1 SC
Carangidae	Decapterus punctatus	-	3 S
	Seriola dumerili	-	1 S
Haemulidae	Haemulon aurolineatum	-	130 S
	Haemulon plumieri	-	27 S
Sparidae	Diplodus holbrooki	1 S	29 S
	Pagrus pagrus	-	15 S
	Stenotomus chrysops	15-20 S	-
Sciaenidae	Equetus umbrosus	-	20 S
Chaetodontidae	Chaetodon sedentarius	-	1 S
Pomacanthidae	Holacanthus bermudensis	1 S	1 SC
Pomacentridae	Chromis cyaneus	-	2 SC
	Chromis enchrysurus	-	30 S
	Chromis insolatus	-	1 S
	Chromis scotti	-	83 SC
	Pomacentrus partitus	-	4 SC
	Pomacentrus variablis	-	9 S
Labridae	Bodianus sp.	-	1 S
	Halichoeres bivittatus	-	5 S
	Halichoeres caudalis	-	2 S
	Halichoeres garnoti	-	7 S
	Halichoeres maculipinna	-	3 S
	Lachnolaimus maximus	-	1 S
	Tautoga onitis	-	1 S
	Thalassoma bifasciatum	-	72 S
Blenniidae	Blenniidae	1 S	-
	Parablennius marmoreus	-	1 C
Gobiidae	Coryphopterus punctipectophorus	-	1 C
	Lythrypnus sp.	-	1 C

Table 6.9 Abundance of fish species caught by vertical longlines during summer, 1980 sampling. N = number of lines deployed and n = number of lines which caught fish.

		STATION		
Family	Species	IS04	MS04	OS04
Carcharhinidae	*Rhizoprionodon terraenovae*	+ 2	+ 1	-
Batrachoididae	*Opsanus pardus*	-	-	+ 1
Serranidae	*Centropristis ocyurus*	-	+ 2	-
	Centropristis striata	-	+ 13	+ 6
	Diplectrum formosum	-	+ 1	-
Haemulidae	*Haemulon plumieri*	-	+ 1	-
Sparidae	*Pagrus pagrus*	-	+ 2	+ 1
n/N		2/8	6/8	3/8
Total number of fish		2	20	8
Catch per reel (n)		1.0	3.3	2.7
Total soak time (hrs) of n lines		6.4	9.3	14.2
Catch per hr		0.3	2.2	0.6

Table 6.10 Abundance of fish species caught by hook and line during summer 1980 sampling. N = number of lines deployed and n = number of lines which caught fish.

Family	Species	STATION ISO4	MSO4	OSO4
Congridae	Conger oceanicus	-	-	+ 1
Serranidae	Centropristis ocyurus	-	+ 4	-
	Centropristis striata	+ 1	+ 9	+47
Carangidae	Seriola dumerili	-	-	+ 1
Lutjanidae	Rhomboplites aurorubens	-	-	+ 1
Haemulidae	Haemulon plumieri	-	+ 2	-
Sparidae	Pagrus pagrus	-	-	+ 2
n/N		1/7	4/6	5/8
Total number of fish		1	15	52
Catch per reel (n)		1.0	3.8	10.4
Total soak time (hrs) of n lines		1.2	4.4	2.2
Catch per hr		0.8	3.4	23.6

Table 6.11 Abundance of fish species caught by Antillean traps during summer, 1980. N = number of traps deployed and n = number of traps which caught fish.

		STATION		
Family	Species	IS04	MS04	OS04
Serranidae	Centropristis striata	+ 4	-	+ 14
Haemulidae	Orthopristis chrysoptera	+ 2	-	-
Sparidae	Pagrus pagrus	-	-	+ 2
	Stenotomus aculeatus	+ 7	+ 7	-
Balistidae	Monacanthus hispidus	-	+ 1	-
n/N		1/2	1/2	2/5
Total number of fish		13	8	16
Catch per reel (n)		13.0	8.0	8.0
Total soak time (hrs) of n traps		2.6	3.0	7.0
Catch per hr		5.0	2.7	2.3

Table 6.12 Catch/effort values of demersal teleosts caught off North Carolina at the inner, middle, and outer shelf stations for summer 1980.

	Total Number	Number/Hour	Total Weight (Kg)	Kg/Hour
Station IS04				
Trawl	4115	3686	228.70	204.81
Hook and line	1	< 1	0.55	0.45
Trap	13	5	2.05	0.80
Longline	0	0	0	0
Station MS04				
Trawl	2628	2585	172.10	169.28
Hook and line	15	3	4.15	0.95
Trap	8	3	0.48	0.16
Longline	19	2	5.32	0.57
Station OS04				
Trawl	-	-	-	-
Hook and line	51	23	39.40	10.267
Trap	16	2.3	9.70	1.39
Longline	8	< 1	7.35	0.52

Virginia and North Carolina (Pearson 1932). This composition can be explained by the fact that trawl tows were made on the sand bottom adjacent to untrawlable live bottom areas.

Species composition of trawl collections at MS04 was similar to those reported by Powles and Barans (1980). Fewer fish were sampled compared to IS04, but the number of fish families and species increased. An interesting comparison between IS04 and MS04 was noticed with regard to the number of *Stenotomus aculeatus* sampled. *Stenotomus aculeatus* was the most abundant species by number at both IS04 and MS04 despite the fact that sampling at the two sites was done over different substrate types. How this phenomenon relates to feeding is discussed in Chapter 7.

Of the ten most abundant species caught by trawl at all North Carolina stations, five were also found to be abundant off South Carolina (Table 6.3 of Volume I). These species were *Stenotomus aculeatus*, *Monacanthus hispidus*, *Apogon pseudomaculatus*, *Haemulon aurolineatum*, and *Equetus umbrosus*. Moreover, *S. aculeatus* was the most abundant species in trawl collections for both North Carolina and South Carolina.

Since species composition differed from IS04 to MS04, it was not surprising that the species composition at IS04 differed from the inshore stations off South Carolina (Volume I). However, eight of the 10 most abundant species collected at MS04 were represented in at least one of the lists of abundant species from the middle shelf stations off South Carolina.

Many studies have been done concerning biomass of natural tropical and subtropical reefs. Powles and Barans (1980) used a trawl similar to the one used in this study and found that total biomass (kg ha^{-1}) for a sponge-coral area (32 - 37 m) off Charleston, South Carolina, equaled 27.3 kg ha^{-1}, which was about half the value calculated at MS04 (58.4 kg ha^{-1}). Mean biomass from five other studies (Brock 1954, Odum and Odum 1955, Bardach 1959, Randall 1963, Fast 1974) was 632 kg ha^{-1}, an order of magnitude greater than the mean biomass estimate in this study (69 kg ha^{-1}). The discrepancies among estimates can be explained by variations in gear type, sampling duration, depth and location of these studies. For example, the studies that contributed to the mean biomass of 632 kg ha^{-1} were done in shallow tropical waters that are probably more productive than live bottoms off North Carolina. In addition, the larger, predatory species associated with live bottoms, such as serranids, lutjanids, and carangids, are rarely sampled by trawl, the gear used in this study.

Mean biomass values for total nekton and demersal teleosts in South Carolina (Volume I) were 46.6 and 31.0 kg ha^{-1}, respectively, which were considerably less than the values calculated off North Carolina (69.6 and 48.7 kg ha^{-1}). Additional sampling efforts should help determine whether these differences reflect real conditions or sampling variability.

Highly diverse communities of reef fish depend on a number of factors, such as an adequate amount of hard substrate for the attachment of epibenthic organisms, adequate supplies of nutrients and solar radiation, and relatively stable conditions of cover and water temperature (Emery 1978). The sand bottom habitat at IS04 probably lacked these characteristics compared to MS04; therefore, overall diversity values at IS04 were lower than the live bottom area sampled at MS04.

The night trawls at MS04 clearly had greater diversity indices than day trawls (Table 6.5), especially when collection No. 809129 is excluded. This is a reasonable exclusion since only six individuals (four species) were caught in that trawl. The increased nocturnal activity of some fish families sampled, such as Haemulidae, Apogonidae, and Sciaenidae (Helfman 1978), is one explanation. In addition, some species can visually avoid the trawl during the day and would not be captured.

Species diversity calculated in this study cannot be compared with diversity found in studies using such methods as explosives (Talbot and Goldman 1973), fish poison (Smith 1973), underwater television (Smith and Tyler 1973, Alevizon and Brooks 1975), and Scuba (Gladfelter et al. 1980). Each of these methods samples a different fraction of the complex reef community; therefore, any measurement of diversity using these methods is limited by incomplete sampling. The trawl used in this study was limited similarly.

The lack of a standardized method of calculating diversity also inhibits comparisons with previous studies. For example, in this study, pooled diversity by day and night was calculated for each station using the Shannon index ($\log_2$). Similar studies used the Levins index (Sale and Dybdahl 1975), a mean estimate of diversity from successive pooled samples (Alevizon and Brooks 1975), and the Shannon index based on natural logarithms (Smith and Tyler 1972). The only comparable study is the sand bottom demersal study of Wenner et al. (1979), in which the range of diversity values calculated for the 19 - 27 m zone encompassed the individual values estimated for IS04 trawl collections.

Although estimates of community composition were limited because trawling was not done at OS04 and trawls were made on sand bottom at IS04, live bottom and sand bottom species clustered separately. Species composition at MS04 appeared to differ greatly from day to night, which is indicative of the changeover characteristic of reef fish communities (Hobson 1972, Hobson 1974, Helfman 1978, Smith 1978). Analysis of future trawl data and food habit analyses should provide some explanations of these cluster results by determining if the diel patterns are seasonal, depth related, or a function of feeding relationships between the reef fish and their epibenthic environment.

Dive activities at IS04 were hampered by poor visibility and did not yield much information. However, results at MS04 were useful because of the identification of two priority species (Mycteroperca phenax and M. microlepis) that were not obtained by other gear types. In addition, divers sighted or collected many of the smaller reef fish, including members from the families Pomacentridae, Labridae, Pomacanthidae, and Chaetodontidae. Diving results at MS04 support the findings of others (Stone et al. 1979) that visual counts and collections of fish by divers are valuable techniques for assessing reef fish communities.

The results of the community composition analysis, as well as those of species composition and abundance, biomass, and diversity, are subject to qualifications. Problems in both the sampling design and the analysis of data probably have resulted in underestimates of numerical abundance, diversity and biomass. The difficulty of sampling the areas of extreme relief associated with live bottoms restricted the numbers and kinds of fishes obtained, especially the large, dominant predators and small cryptic species. Further, annual variations in the influence of dominant water masses in Onslow Bay (Cerame-Vivas and Gray 1966) cause large seasonal variations in water temperature (7 - 28°C) that result in migration and stunning of some of the larger, predatory species (Huntsman and Manooch 1978, Manooch 1978) and, probably, a high rate of mortality among smaller, less mobile reef fish species. Seasonal sampling, rather than a single sampling, is needed for an accurate assessment of the nektonic community.

IMPACT/ENHANCEMENT

The major impact of hydrocarbon exploration activities occurs in the process of exploratory drilling operations. The physical obstruction of a small area of the bottom (where the platform legs and well casing are placed) is minor compared to the more extensive smothering of adjacent live bottom by drilling muds and cuttings. The major impact to live bottom nektonic communities is expected to be the conversion of an area in the vicinity of the drilling activity to a soft bottom habitat, thus removing it as a feeding and refuge site for motile organisms. Through food chain transfers, nekton may become contaminated with the organic and metal compounds present in the waters released at the platform during drilling. Unless large numbers of wells are drilled in a small area, measurable impacts will be restricted to the vicinity of the drilling platform.

The only significant enhancement of live bottom systems occurs as a result of increased surface area of hard substrate provided by the drilling platform. In non-live bottom areas platforms provide an artificial reef which is colonized by typical live bottom fishes. On live bottoms such platforms are expected to provide a physical habitat that can support an increased number of fishes. Because the platform extends from the surface to the bottom, diversity of fishes may be increased by the addition of extended relief.

CONCLUSIONS

Species composition at MS04 was very similar to that found in the South Carolina and Georgia effort (Volume I). Stenotomus aculeatus, the most abundant species in trawl collections of both North Carolina and South Carolina, were caught over sand bottoms several hundred metres away from the live bottom at IS04 as well as on the live bottom itself on MS04. Their presence in both habitats indicates that this species plays a role in both communities and is an example of the adaptability of reef fishes (Smith 1978, Huntsman 1979).

Among the more significant results of the nekton studies were the day/night differences in community composition which occurred at MS04. This pattern allows greater utilization of the live bottom area resulting in higher diversity and greater specialization of fishes than in communities without this diel pattern. These increases in diversity and specialization, in turn, probably help in maintaining the high fish productivity of such habitats.

Biomass estimates for IS04 and MS04 were considerably higher than the mean biomass values for inner and middle shelf stations reported in Volume I, yet they were an order of magnitude lower than the mean biomass values calculated from other studies done on tropical and subtropical fish.

As noted in Volume I, cluster analysis showed definite diel differences in community composition.

Underwater television and diver observations provided additional qualitative information about the nektonic community. For example, these observations indicated the presence and numbers of large predatory species, such as groupers, and small cryptic species, such as gobies and blennies.

Offshore drilling efforts may convert live bottom areas into soft bottom habitats, which probably would have a negative effect on species diversity and composition in the impacted area.

The greatest opportunity for enhancing the nektonic community associated with live bottoms may be derived from the increased surface area that drilling platforms would provide. Invertebrate populations that support live bottom fishes would be enhanced due to the increased attachment area.

CHAPTER 7

FOOD HABITS AND TROPHIC RELATIONSHIPS OF FISHES

INTRODUCTION

Food habit studies of reef fishes are numerous; however, few investigators have attempted to describe trophic relationships of reef fish communities (Odum and Odum 1955, Hiatt and Strasburg 1960, Hobson 1974, Parrish and Zimmerman 1977). Since the benthic invertebrate fauna is important to the energy flow in a reef ecosystem, the analysis of prey items eaten by predator fish species can help describe this transfer of energy. In this portion of the study, the three major goals were to quantify the food items identified from stomachs of predator species, describe the relationship between abundance of available food and prey items ingested, and comment on the potential impact or enhancement of drilling activities on the food habits and trophic relationships of important live bottom fishes.

METHODS

Laboratory Analysis:

Seven species of reef fish initially were chosen as priority species based on their importance to the recreational and commercial snapper-grouper fisheries in the South Atlantic Bight (Huntsman 1976, Ulrich et al. 1977); they were *Centropristis striata*, *Epinephelus niveatus*, *Lutjanus campechanus*, *Mycteroperca microlepis*, *Mycteroperca phenax*, *Pagrus pagrus*, and *Rhomboplites aurorubens*.

Since the food habits study was completed for only one priority species, *Centropristis striata*, three non-priority species were also analyzed in this study (*Stenotomus aculeatus*, *Haemulon plumieri*, and *Haemulon aurolineatum*). These species should be considered priority species in future studies for the following reasons:

1) *S. aculeatus* appears to be an important species in at least two of the three depth zones (inner and middle shelf) with respect to abundance and biomass;
2) *H. plumieri* is an important species to both commercial and recreational fishermen (Manooch 1978);
3) *H. aurolineatum* is caught by recreational headboat fishermen and could be available in commercial quantities off South Carolina (Manooch and Barans, in preparation).

Laboratory analysis of fish stomachs was conducted on priority and non-priority species. The stomachs were removed from the 10% formalin solution in which they had been preserved, soaked in water for one day, and stored in 50% isopropanol. Total stomach content volume was measured by liquid displacement in a graduated cylinder and sorted to the lowest taxonomic level using a Bausch and Lomb StereoZoom "7" dissecting microscope.

Voucher specimens of prey species were saved and information on each prey item (actual or restored length in millimetres, number of items, volume of items, and major taxon) was recorded.

Data Analysis:

The food habits analyses were based on the comparison of calculated indices of relative importance (Pinkas et al. 1971). The index was calculated by the following equation:

$$IRI = (N + V)F$$

where N = numerical percentage of each food item, V = volumetric percentage of each food item and F = frequency of occurrence, in percent, of each food item. Prey items for each fish species were analyzed by species and by major taxon. Values of N, V, and F by major taxon were plotted (after the method of Pinkas et al. 1971). Stomachs from all stations were grouped together for *C. striata*, *H. plumieri*, and *H. aurolineatum* because of small sample sizes at individual stations (≤ 10). Sufficient numbers of *S. aculeatus* stomachs were obtained to allow comparison of IS04 and MS04 samples.

RESULTS

Centropristis striata:

The five most important major taxa in the diet of black sea bass were Decapoda, Gastropoda, Pisces, Anthozoa and Pelecypoda (Figure 7.1). The four most important prey items identified were the crabs *Stenorhynchus seticornis* and *Portunus spinicarpus*, the filefish *Monacanthus hispidus*, and the anemone *Ceriantheopsis americanus* (Table 7.1).

Haemulon plumieri:

Decapoda, Polychaeta, algae, Amphipoda, and Mollusca (Pelecypoda and Gastropoda) comprised the most important groups of prey ingested by white grunt (Figure 7.2). The polychaete *Marphysa* sp. had the largest individual index value, followed by majid crabs and the bivalve *Arca zebra* (Table 7.2).

Haemulon aurolineatum:

Major taxonomic groups of food consumed by tomtate were Decapoda, Pelecypoda, algae, and Gastropoda (Figure 7.3). Identifiable prey items included the crabs *Albunea gibbesii* and *Mithrax forceps*, and the chiton *Acanthochitona pygmaea* (Table 7.3).

Stenotomus aculeatus:

The five most important major taxa found in stomachs from all southern porgy collected were Decapoda, algae, Polychaeta, Gastropoda, and Copepoda (Figure 7.4). The three most important identifiable prey items were *Ophiothrix angulata*, a polychaete from the family Chrysopetalidae, and a xanthid crab (Table 7.4). A comparison of prey taxa from IS04 and MS04 (Figure 7.5) indicated that decapods ranked first at IS04, followed closely by algae; whereas molluscs and decapods were preferred by *S. aculeatus* sampled at MS04. Algae did not appear to be as important to the diet of *S. aculeatus* at MS04 as at IS04.

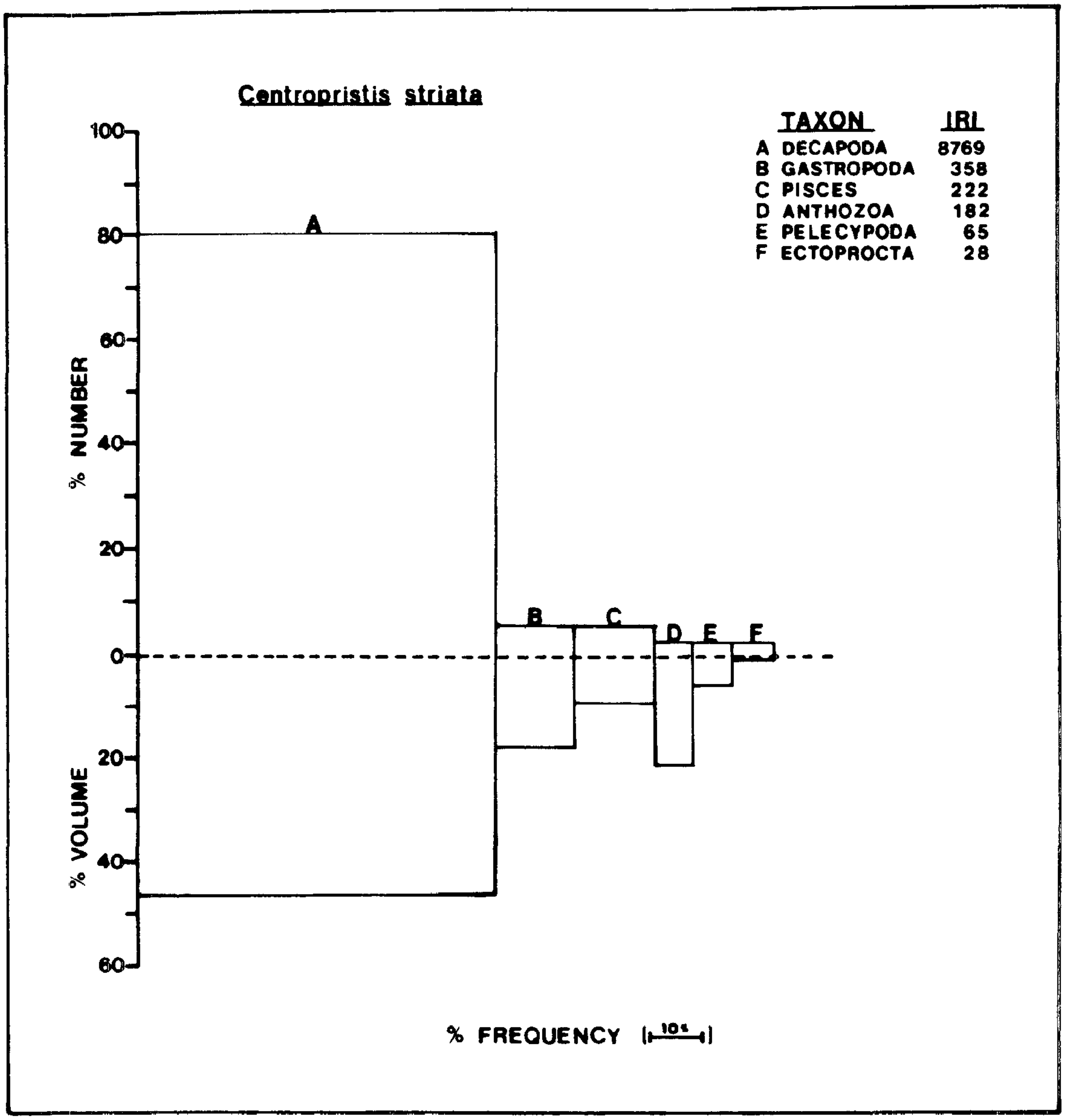

Figure 7.1. Relative importance of prey items, by major taxon, identified from Centropristis striata stomachs collected at IS04, MS04, and OS04.

Table 7.1 Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in Centropristis striata stomachs from North Carolina for summer 1980.

Taxon Food Item	F	N	V	IRI
Cnidaria				
Anthozoa				
Ceriantheopsis americanus	7.69	2.78	20.92	182.25
Mollusca				
Gastropoda				
Nudibranchia	7.69	2.78	1.61	33.74
Unidentified Gastropoda	7.69	2.78	16.09	145.13
Total Gastropoda	15.38	5.56	17.70	357.74
Pelecypoda				
Arca zebra	7.69	2.78	5.63	64.67
Crustacea				
Decapoda				
Brachyura				
Calappa sp.	7.69	2.78	2.41	39.93
C. angusta	7.69	2.78	4.83	58.49
Pilumnus sp.	7.69	2.78	2.41	39.93
P. sayi	7.69	2.78	4.02	52.30
Pinnotheres sp.	7.69	2.78	0.08	21.98
Pitho iherminieri	7.69	2.78	1.13	30.02
Portunus spinicarpus	15.38	5.55	12.07	271.09
Ranilia muricata	7.69	2.78	0.80	27.55
Stenocionops furcata coelata	7.69	2.78	1.45	32.50
Stenorhynchus seticornis	15.38	47.22	12.87	924.47
Xanthidae	7.69	2.78	0.80	27.55
Unidentified Brachura	7.69	2.78	3.22	46.11
Total Decapoda	69.23	80.58	46.09	8769.36
Ectoprocta				
Unidentified Ectoprocta	7.69	2.78	0.80	27.55
Pisces				
Monacanthus hispidus	15.38	5.56	8.85	221.62

Number of Stomachs Examined 17
Number of Stomachs with Food 13

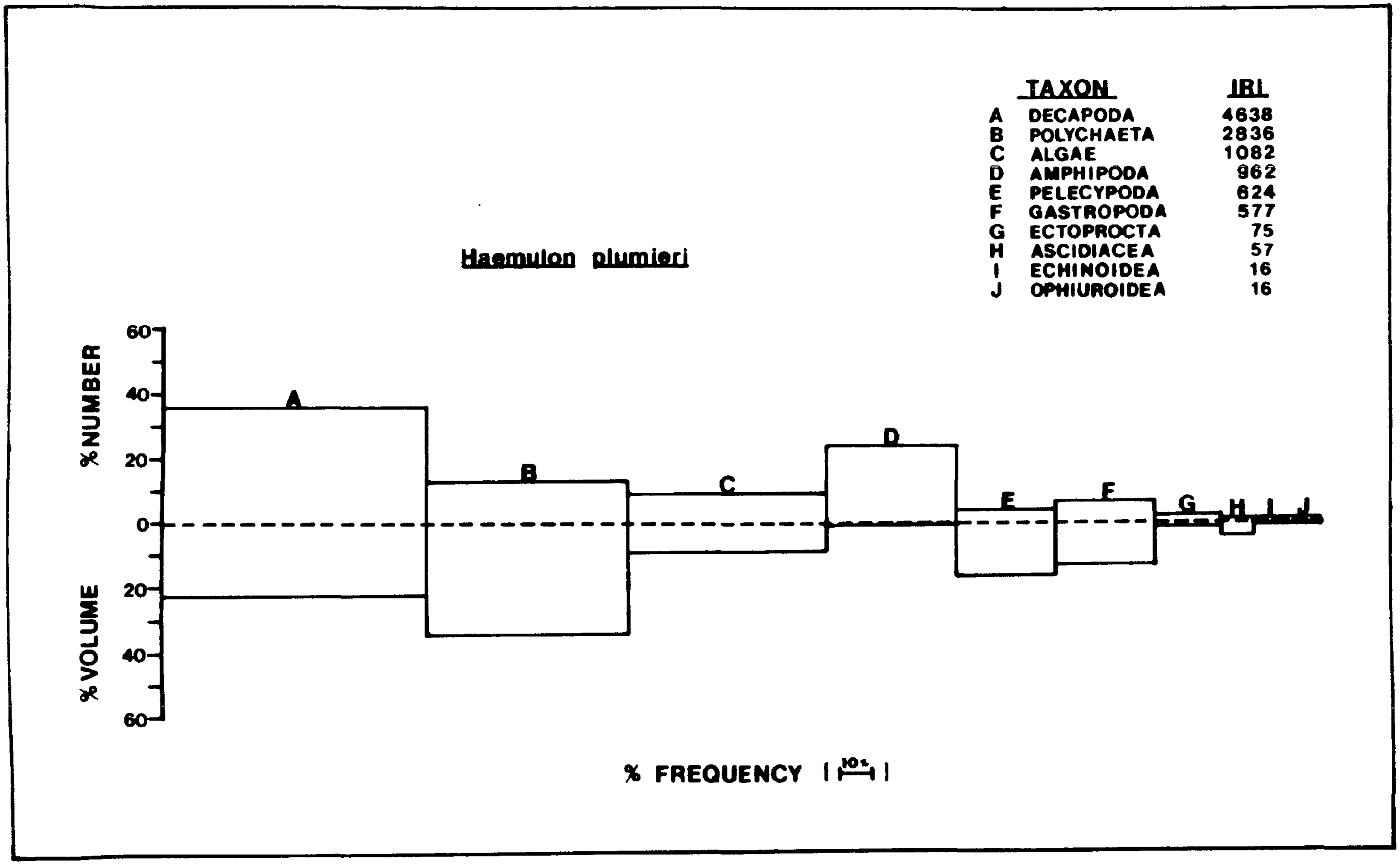

Figure 7.2. Relative importance of prey items, by major taxon, identified from Haemulon plumieri stomachs collected at MS04.

Table 7.2 Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in Haemulon plumieri stomachs from North Carolina for summer 1980.

Taxon Food Item	F	N	V	IRI
Annelida				
Polychaeta				
Drilonereis sp.	10.00	1.56	0.83	23.92
Eunicidae	10.00	1.56	4.15	57.13
Marphysa sp.	40.00	7.81	29.78	1503.72
Unidentified Polychaeta	10.00	1.56	0.00	15.62
Total Polychaeta	60.00	12.50	34.76	2835.60
Mollusca				
Gastropoda				
Alvania auberiana	10.00	1.56	0.00	15.62
Laevicardium sp.	10.00	1.56	0.52	20.81
Lucapinella limatula	10.00	1.56	0.00	15.62
Unidentified Gastropoda	10.00	1.56	12.45	140.13
Total Gastropoda	30.00	6.25	12.97	576.60
Pelecypoda				
Arca zebra	10.00	1.56	15.57	171.26
Diodora cayenensis	10.00	1.56	0.52	20.81
Pteria colymbus	10.00	1.56	0.02	15.83
Total Pelecypoda	30.00	4.69	16.11	624.00
Crustacea				
Amphipoda				
Unidentified Amphipoda	40.00	23.44	0.62	962.40
Decapoda				
Natantia				
Alpheidae	10.00	3.13	0.03	31.56
Unidentified Natantia	20.00	4.69	0.64	106.62
Reptantia				
Anomura				
Pagurus annulipes	10.00	1.56	0.01	15.73
Brachyura				
Majidae	20.00	3.13	12.46	311.74
Metoporhaphis calcarata	10.00	1.56	0.01	15.73
Micropanope sp.	10.00	1.56	0.08	16.45
Mithrax (Mithrax) pleuracanthus	20.00	3.13	1.47	91.97
Osachila semilevis	10.00	1.56	0.21	17.70

Table 7.2 (Continued)

	F	N	V	IRI
Pelia mutica	10.00	1.56	0.10	16.66
Pilumnus sayi	10.00	1.56	1.04	26.00
Pitho lherminieri	10.00	3.13	0.54	36.64
Xanthidae	10.00	1.56	0.10	16.66
Unidentified Brachyura	10.00	3.13	0.11	32.39
Unidentified Decapoda	20.00	4.69	5.22	198.20
Total Decapoda	80.00	35.95	22.02	4637.60
Ectoprocta				
Unidentified Ectoprocta	20.00	3.13	0.63	75.20
Echinodermata				
Echinoidea				
Arbacia punctulata	10.00	1.56	0.03	15.93
Ophiuroidea				
Ophiothrix angulata	10.00	1.56	0.02	15.83
Ascidiacea				
Unidentified Ascidiacea	10.00	1.56	4.15	57.13
Algae				
Unidentified Algae	60.00	9.38	8.66	1082.40

Number of Stomachs Examined	12
Number of Stomachs With Food	10

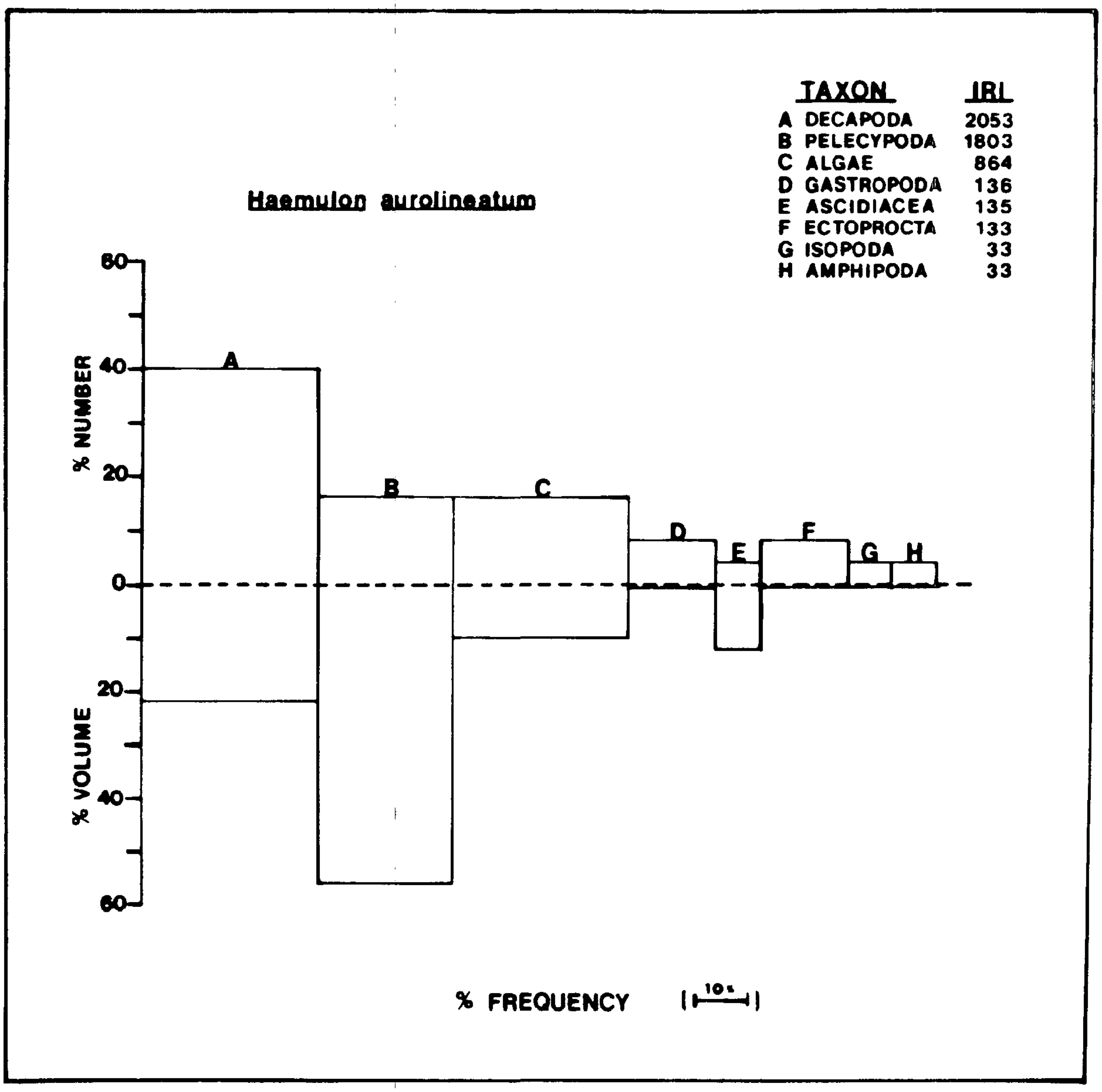

Figure 7.3. Relative importance of prey items, by major taxon, identified from <u>Haemulon aurolineatum</u> stomachs collected at MS04.

Table 7.3 Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in *Haemulon aurolineatum* stomachs from North Carolina for summer 1980.

Taxon / Food Item	F	N	V	IRI
Mollusca				
Gastropoda				
Acanthochitona pygmaea	8.33	4.00	0.19	34.90
Unidentified Gastropoda	8.33	4.00	0.00	33.32
Total Gastropoda	16.66	8.00	0.19	136.44
Pelecypoda				
Unidentified Pelecypoda	25.00	16.00	56.13	1803.25
Crustacea				
Isopoda				
Unidentified Isopoda	8.33	4.00	0.00	33.33
Amphipoda				
Unidentified Amphipoda	8.33	4.00	0.00	33.33
Decapoda				
Natantia				
Unidentified Natantia	8.33	4.00	0.75	39.57
Reptantia				
Anomura				
Paguridae	8.33	4.00	8.42	103.46
Brachyura				
Albunea gibbesii	8.33	4.00	7.48	95.63
Mithrax foreceps	8.33	4.00	4.68	72.30
Unidentified Decapoda	16.67	24.00	0.28	404.75
Total Decapoda	33.33	40.00	21.61	2053.46
Ectoprocta				
Unidentified Ectoprocta	16.67	8.00	0.00	133.36
Ascidiacea				
Unidentified Ascidiacea	8.33	4.00	12.16	134.61
Algae				
Unidentified Algae	33.33	16.00	9.92	863.91

Number of Stomachs Examined 13
Number of Stomachs With Food 12

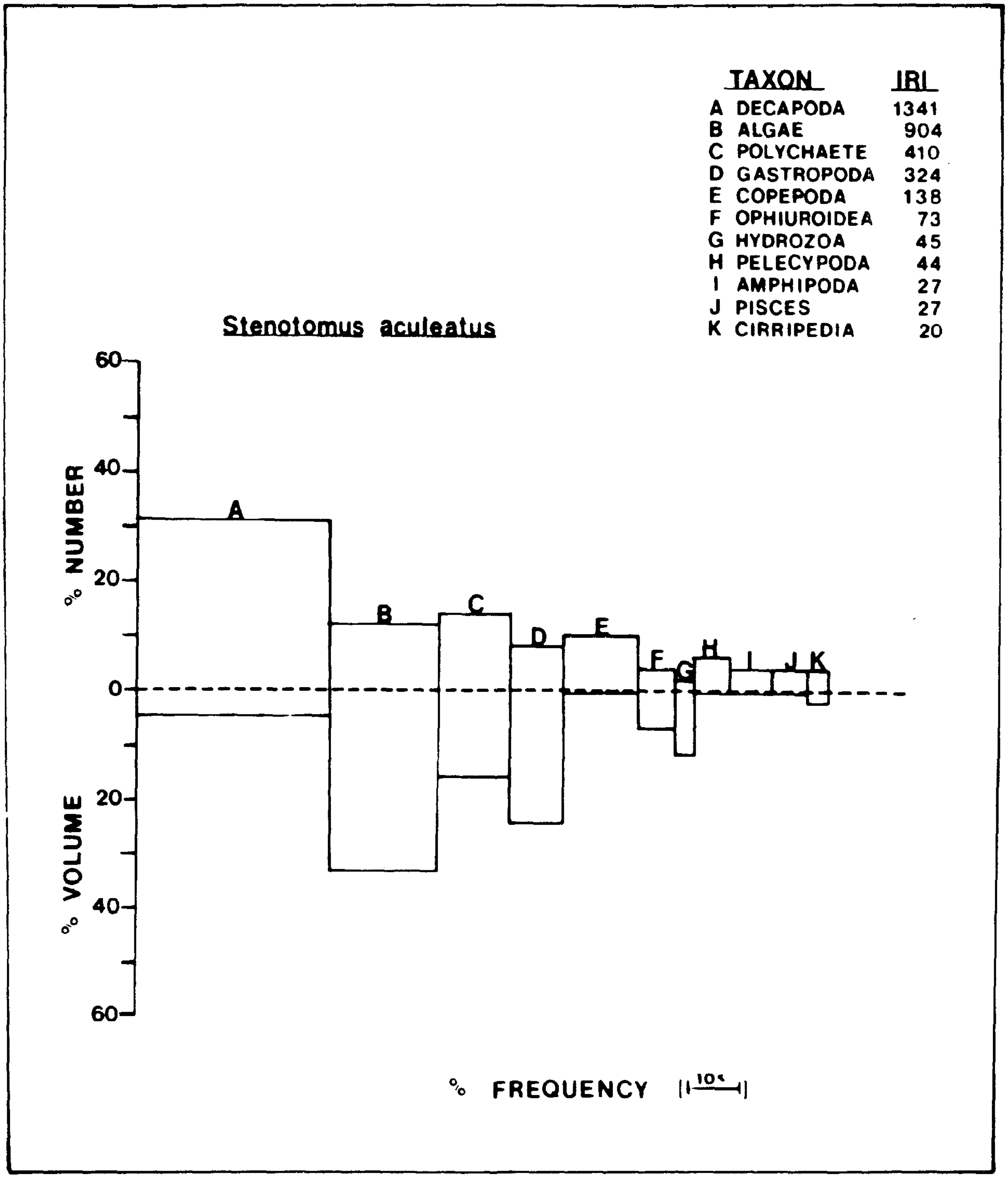

Figure 7.4. Combined relative importance of prey items, by major taxon, identified from <u>Stenotomus aculeatus</u> stomachs collected at IS04 and MS04.

Table 7.4 Percent frequency occurrence (F), percent number (N), percent volume (V) and index of relative importance (IRI) of food items in Stenotomus aculeatus stomachs from North Carolina for summer 1980.

Taxon Food Item	F	N	V	IRI
Cnidaria				
Hydrozoa				
Unidentified Hydrozoa	3.33	2.00	11.40	44.62
Annelida				
Polychaeta				
Chrysopetalidae	3.33	2.00	9.77	39.19
Phyllodoce sp.	3.33	2.00	0.00	6.66
Unidentified Polychaeta	6.67	10.00	7.00	113.39
Total Polychaeta	13.33	14.00	16.77	410.16
Mollusca				
Gastropoda				
Unidentified Gastropoda	10.00	8.00	24.43	324.30
Pelecypoda				
Musculus lateralis	3.33	2.00	0.49	8.29
Unidentified Pelecypoda	3.33	4.00	0.16	13.85
Total Pelecypoda	6.67	6.00	0.65	44.36
Crustacea				
Copepoda				
Unidentified Copepoda	13.33	10.00	0.32	137.56
Cirripedia				
Unidentified Cirripedia	3.33	4.00	1.95	19.81
Amphipoda				
Unidentified Amphipoda	6.67	4.00	0.00	26.68
Decapoda				
Unidentified Natantia	20.00	16.00	0.49	329.80
Anomura				
Paguridae	3.33	2.00	0.00	6.66
Brachyura				
Xanthidae	3.33	2.00	3.25	17.52
Unidentified Brachyura	10.00	6.00	0.65	66.84
Unidentified Decapoda	3.33	6.00	0.16	20.51
Total Decapoda	36.67	32.00	4.56	1340.66

Table 7.4 (Continued)

Taxon Food Item	F	N	V	IRI
Echinodermata				
Ophiuroidae				
Ophiothrix angulata	6.67	4.00	7.00	73.37
Pisces				
Fish scales	6.67	4.00	0.00	26.66
Algae				
Unidentified Algae	20.00	12.00	33.22	904.40

Number of Stomachs Examined	32
Number of Stomachs with Food	30

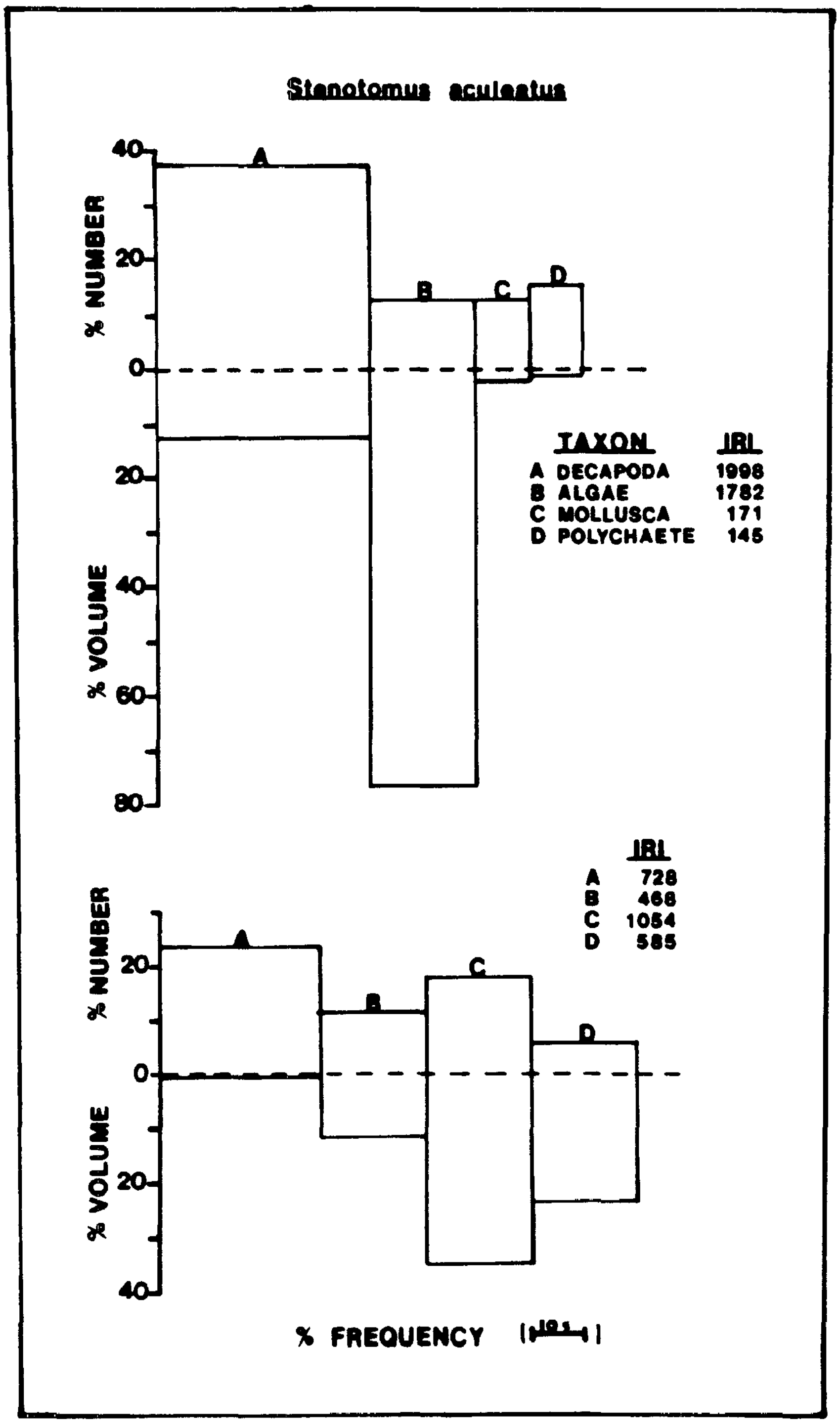

Figure 7.5. Comparison of relative importance of prey items, by major taxon, identified from Stenotomus aculeatus stomachs collected at IS04 (top) and MS04 (bottom).

DISCUSSION

The most important major taxon found in the stomachs of all fish analyzed was Decapoda. In terms of percent invertebrate biomass sampled by dredge, decapods were sixth and eighth at IS04 and MS04, respectively (Figure 5.4). If decapods were adequately sampled, then it appears that the reef fish analyzed had a dietary preference for this taxon.

The three major taxa found in stomachs of Centropristis striata were the same as those found by Link (1980): Decapoda, Gastropoda, and Pisces. Of the four predator species analyzed, C. striata was the most specialized with respect to prey items ingested. One reason for this could be the apparent preference for the arrow crab Stenorhynchus seticornis, which accounted for 47.2% by number of the food items found. However, C. striata is known to have a high rate of stomach eversion due to depth changes during capture (Link 1980). Because Stenorhynchus seticornis has long legs and a long, spiny rostrum, it might be retained in the stomachs when other less spiny material is expelled. Decapoda was also the most important prey taxon in C. striata stomachs from summer collections in South Carolina (Volume I, Figure 7.1).

Published food studies for Stenotomus aculeatus do not exist at the present time. Food habits have been studied in other sparid reef species, such as Pagrus pagrus (Manooch 1977) and Calamus sp. (Parrish and Zimmerman 1977). Comparisons of S. aculeatus with these species are questionable, however, because S. aculeatus is smaller in length, weight, and mouth size. Therefore, the type, size and amount of prey ingested are restricted.

The volume of algae found in the stomachs of S. aculeatus was much higher for IS04 samples than for MS04 samples. Dredge efforts at IS04 did not collect much algae, yet percentage volume of algae in stomachs from S. aculeatus caught there was close to 80%. Algal species dominated the epibenthic community (in percent biomass collected by dredge) at MS04, but stomachs of S. aculeatus from this site contained a relatively low percentage (17%) of algae. Stenotomus aculeatus stomachs collected at IS04 were from relatively barren, sandy bottoms compared to the live bottom at MS04 (see Sampling Methods, Chapter 2). Small, drifting pieces of algae in this sandy area at IS04 may have been ingested because of a lack of preferred live bottom prey. In contrast, the high diversity and abundance of food items available at MS04 may have allowed predator species there to be more selective of benthic animals.

Significant differences were noted between S. aculeatus stomachs analyzed from South Carolina and North Carolina. Decapods, algae, and polychaetes were the three most important prey taxa in North Carolina, compared to fish, pelecypods, and decapods in South Carolina (Volume I, Table 7.5). Additional food habit analyses of S. aculeatus are needed before definitive conclusions can be made about latitudinal differences in prey preferences.

Prey item diversity for Haemulon plumieri was similar to the diversity reported in studies by Beebe and Tee-Van (1928), Randall (1967), and Manooch (1978). Although algae ranked first in terms of biomass at MS04 (Figure 5.4) and occurred in 60% of H. plumieri stomachs analyzed, it was probably a by-product of the ingestion of other prey (Randall 1967).

Food items identified from stomachs of Haemulon aurolineatum were generally the same as those identified in studies by Beebe and Tee-Van (1928), Randall (1967), and Parrish and Zimmerman (1977). Longley and Hildebrand (1941) reported that H. aurolineatum was not as closely linked to reef areas as other haemulids, probably due to its nocturnal foraging behavior on sand bottom areas adjacent to reefs (Parrish and Zimmerman 1977). Future studies should determine whether this species is dependent on sand bottom areas.

Polychaetes ranked second in relative importance in H. plumieri stomachs analyzed, but were totally absent from H. aurolineatum stomachs. Since Marphysa sp., a relatively large polychaete, was the dominant species ingested by white grunt, it is likely that the dietary difference between the two haemulids is related to predator size. The white grunts that fed upon Marphysa sp. were all greater than 300 mm in total length, while no analyzed tomtate grunts were larger than 200 mm in total length.

There were some limitations of the food habits study that should be considered in interpreting the data. Since this project was designed to sample small numbers of stomachs, background studies are needed to validate and compare the results. However, previous studies have been done on only three of the seven priority species off North Carolina: Pagrus pagrus (Manooch 1977), Rhomboplites aurorubens (Grimes 1979), and Centropristis striata (Link 1980). Another problem is that many of the reef fishes are opportunistic feeders (Smith 1978); hence, a decline or absence of a prey item in stomach analyses does not necessarily mean it is unavailable. Therefore, it is possible that prey items not identified at one sampling time will be significant in later analyses of the same predator species. In addition, prey items have different rates of digestion, making it difficult to quantify actual diet intake or preference. Finally, it is impossible to quantify all food items with the same technique: extremely small food items such as amphipods and copepods are difficult to measure volumetrically, while colonial organisms and algae are difficult to count.

IMPACT/ENHANCEMENT

The impact of hydrocarbon exploration activities on the food habits and trophic relationships of priority species of fishes is hard to predict because of the tremendous complexity of reef ecosystems (Bradbury 1977, Huntsman 1979). If such activities resulted in a change of community type from live bottom to soft bottom, economically important families of fish from the snapper-grouper complex such as serranids, lutjanids, sparids, and haemulids probably would migrate away from the area. If the impact were a selective reduction or increase in the numbers of particular prey species, many of the top-level predators (especially the generalized predators) probably would change their feeding to accommodate these changes (Murdoch et al. 1975, Love and Ebeling 1978). However, if the impact were a significant reduction in visibility and chemosensory ability due to high turbidity, feeding by reef species probably would be inhibited (Bardach and Case 1965; de Groot 1969; KleereKoper 1969; Hara 1971; Kittredge 1974).

The enhancement effect of exploration for hydrocarbons probably would be an increase in encrusting organisms and motile invertebrates that support many reef fish species such as sparids and some serranids (Carlisle et al. 1964, Treybig 1971, Hastings et al. 1976). The extension of the epibenthic community to the hard substrate of the drilling platform could lead to an increase in the number and perhaps the diversity of prey items found in live bottom areas. Platforms built on sand bottoms could provide new food sources for fish.

CONCLUSIONS

Decapoda was the most important major taxon found in the stomachs of all fish species analyzed.

Haemulon plumieri, Haemulon aurolineatum and Stenotomus aculeatus appeared to be generalized predators of motile, epibenthic invertebrates associated with the live bottoms. Only Centropristis striata appeared to have a specific preferred food item, the arrow crab Stenorhyncus seticornis.

Impacts of hydrocarbon exploration on the food habits and trophic relationships of priority species probably will be related to 1) effects on the abundance and diversity of benthic prey organisms and 2) reduction of visual and chemosensory abilities of predator species with respect to feeding behavior.

Drilling platforms would provide additional habitats for encrusting and motile invertebrates that support reef fish species. In addition drilling platforms constructed on barren, sandy bottoms could increase the amount of live bottom habitat in certain areas.

CHAPTER 8

METHODOLOGY EVALUATION AND RECOMMENDATIONS FOR FUTURE STUDIES

METHODOLOGY EVALUATION

Suction Sampling:

The airlift suction device proved to be an effective method for collecting organisms scraped from quadrats by divers, particularly small invertebrates and algae. This sampling procedure was the most quantitative of all techniques employed. However, since colonial organisms and algae were not included in quantitative analyses, evaluation of these important components in the community remains undetermined. Limitations of the technique are mainly in the number of samples necessary for adequate characterization of a hard bottom community which has a great variety of microhabitats. Based on species-area curves (Figure 8.1), which did not reach a plateau, more replicate samples are needed to determine the number of species in the community.

Grab Sampling:

In areas inaccessible for diver sampling with the airlift suction samplers, remote sampling with a Smith-McIntyre grab was used. However, the use of a grab sampler is much less efficient than the airlift suction device for quantitative sampling of live bottom areas. Grabs are designed for sampling soft (sand and mud) substrates, and the only successful grab collections from live bottom are from sediment covered areas. These samples are more representative of soft bottom habitats. Further, complete removal of all organisms from rock substrates, as accomplished with the airlift suction device, was impossible with the grab sampler. For these reasons, any quantitative comparison of data collected by suction sampler (IS04 and MS04) with data collected by grab sampler (OS04) is questionable. Unfortunately, no other practical technique is available for taking quantitative samples on hard substrates from a ship.

Dredge Sampling:

Dredge sampling of live bottom was an excellent technique for qualitative sampling of live bottom areas. The Cerame-Vivas dredge was very effective in capturing epibenthic organisms. However, the species-area curve did not begin to level after two dredge collections at any of the live bottom areas (Figure 8.2). Obviously, a complete qualitative description of the live bottom areas would require more than the two replicate dredge samples taken at each station.

Television Transect Sampling:

Television transects were an effective technique in a general description of the live bottoms and in a quantitative assessment of the percent live bottom in the study areas sampled (MS04 and OS04), particularly in delineating the extent of live bottom and the transitions which occur from ledges and crevices to reef flats. Often ledges not appearing on fathometer records were observed with television. This method was less useful in a quantitative assessment of organisms. Only a few large invertebrates and a few fish could be identified to

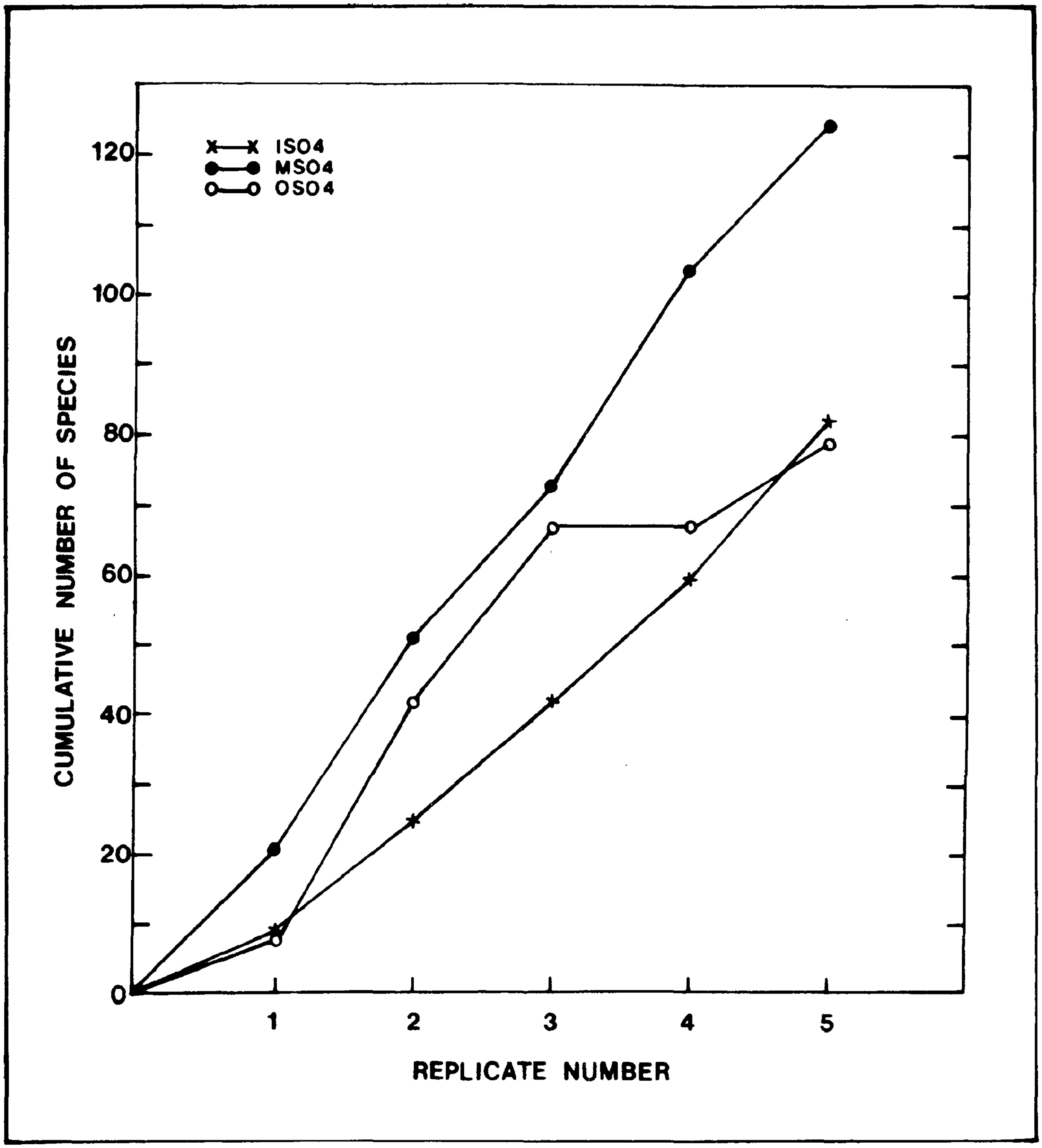

Figure 8.1. Species-area curves showing accumulation of invertebrate and algal species with increasing replicate number using airlift suction (IS04, MS04) and Smith-McIntyre grab samplers (OS04).

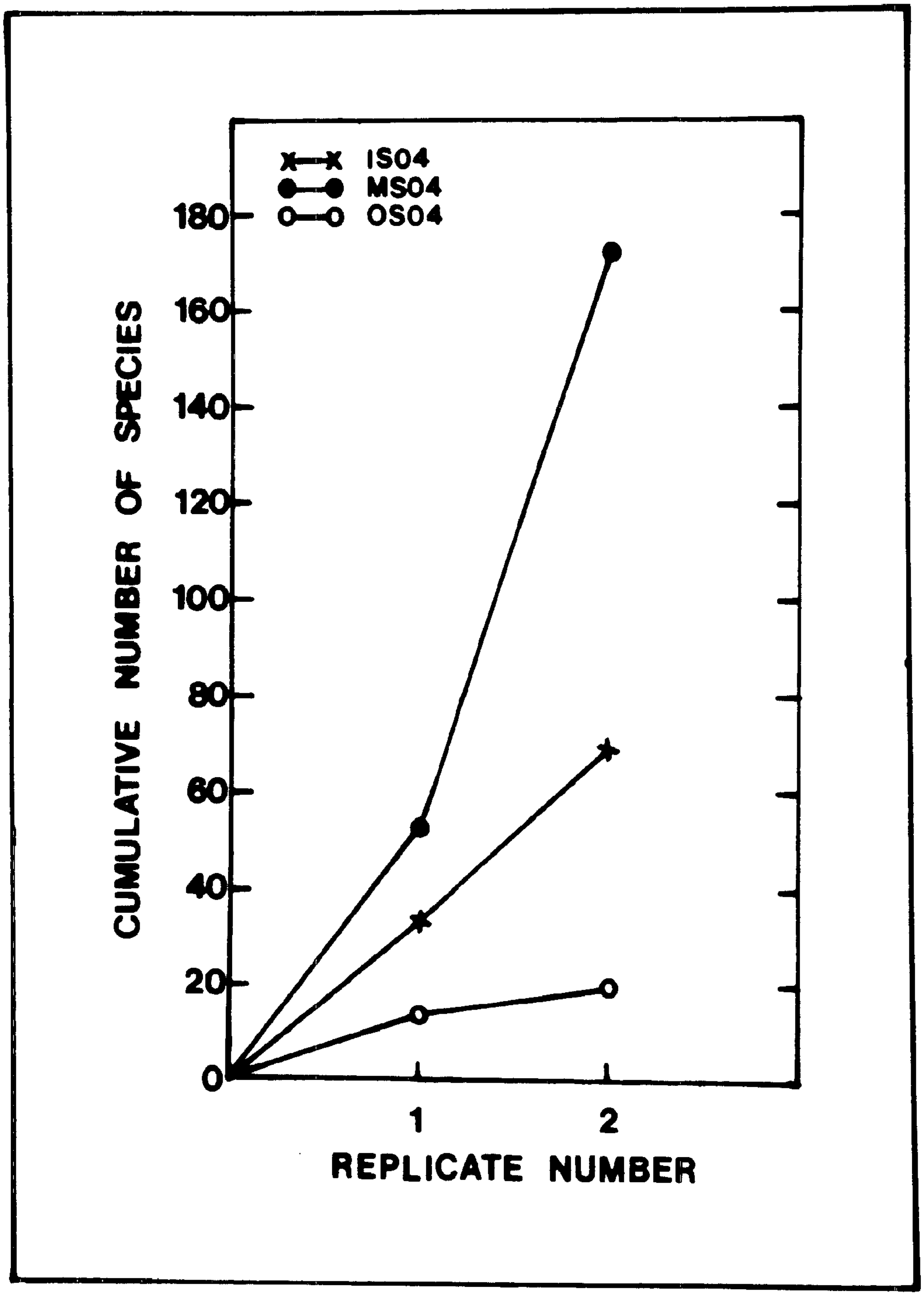

Figure 8.2. Species-area curves showing accumulation of invertebrate and algal species with increasing replicate number using Cerame-Vivas rock dredge at IS04, MS04, and OS04. Distance for each tow was approximately 0.15 km.

species; large macroalgae could be identified only as a group. Further, since space for attachment is an important and often limiting resource in hard bottom communities, evaluation of the frequency of occurrence of erect and, therefore, more easily observed species may add little to the understanding of community structure of these areas.

Trawl Sampling:

The U.R.I. 40/54 highfly trawl was employed to capture demersal fishes, and catch records proved this method to be the most successful fishing gear used. Compared to other gears used, trawling produced high values for diversity, abundance, and catch per unit effort for fishes. The differences noted between day and night catches at MS04 indicated that day-night sampling was a good sampling strategy. Future sampling efforts should provide time for additional trawling, since greater sample size would increase the power of the statistical analyses for fishes.

The 40/54 highfly trawl also was used to sample invertebrates and algae. Trawling was an effective qualitative method of capturing demersal invertebrates. However, the normal (Jaccard) cluster analysis of invertebrate collections taken with a trawl at MS04 (Figure 5.6) indicated that trawling is an inadequate method for sampling attached invertebrate and algal species. In general, there was low similarity between replicate trawl samples taken at MS04, suggesting that "success" in a catch is fairly unpredictable. Six replicate trawls were not an adequate sample size at MS04 (Figure 8.3). Data taken from these trawls should be used to supplement species lists at the sites but should not be included in a cluster analysis to determine similarity or dissimilarity of areas sampled.

Rod and Reel Sampling:

Rod and reel fishing gear was employed to capture predator species. Results from catch records show this to be a good method of obtaining demersal species and the large predatory fishes missed by trawls, such as those inhabiting holes and crevices. A limiting factor to this gear is vessel mobility, as maneuverability and maintenance of position over a potential fishing site can be difficult from large (25 - 35 m) research vessels. Hook and line efforts are much more efficiently conducted from smaller, more maneuverable vessels in the 12 - 18 m range.

Fish Trap Sampling:

The Antillean "S" fish trap was employed to capture demersal species. The results of the trapping effort indicated few fish would enter the trap. This problem appears to be related to season and not to the trap itself. In North Carolina, commercial trapping of demersal fish (primarily Centropristis striata) is successful only during the colder months of the year. Future sampling design would benefit from increased trapping in winter and spring periods to supplement catches from other gear types (trawl and hook and line). Reduced trapping effort during the summer and fall periods should be replaced with more hook and line effort.

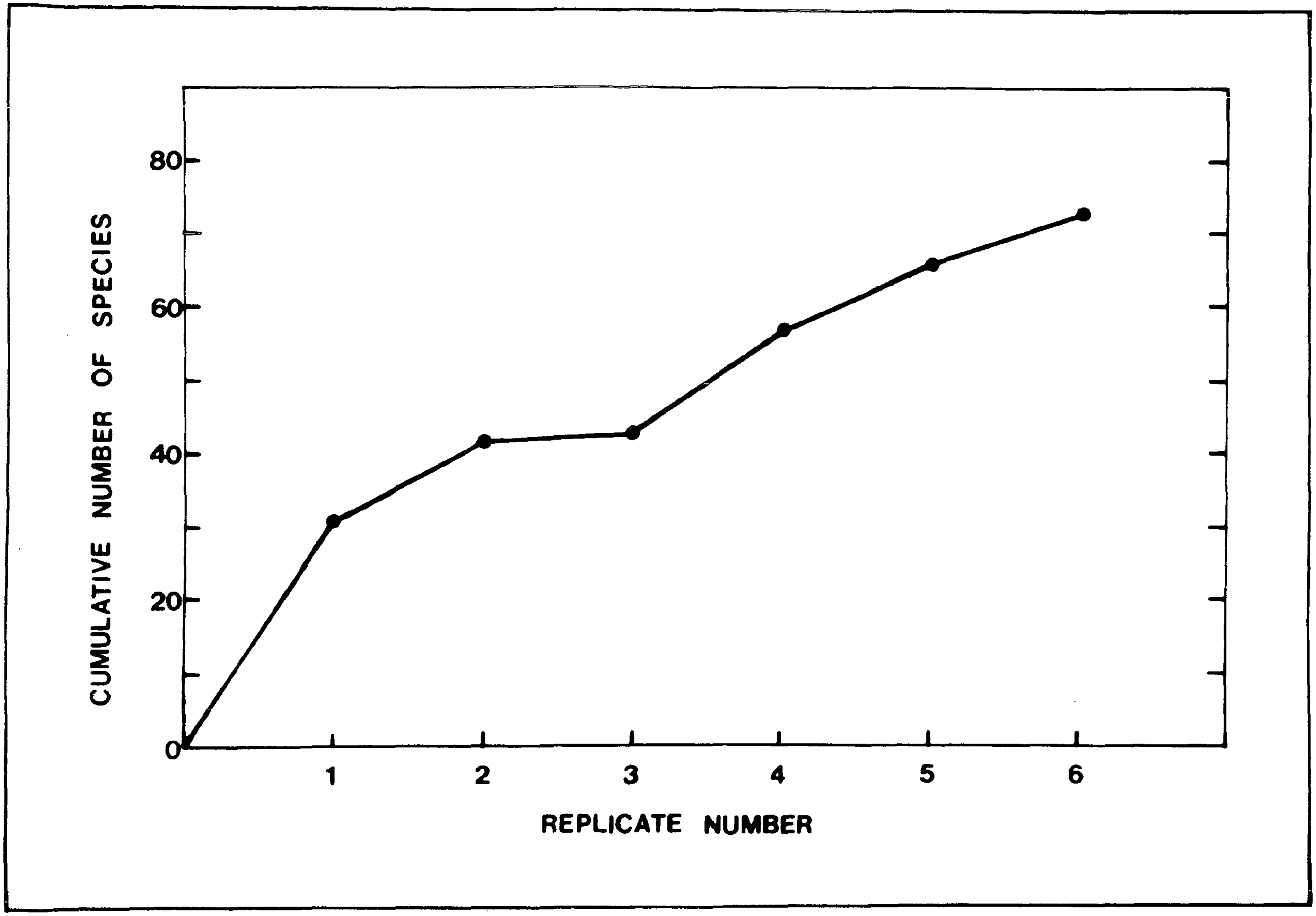

Figure 8.3. Species-area curve showing accumulation of invertebrate and algal species with increasing replicate number using 40/54 trawl at MS04.

Longline Sampling:

Vertical longlines were employed to capture predator species. Catch records indicate that this method is not effective in sampling fishes. Some demersal and pelagic species were caught; but unlike the Antillean fish trap, the "catchability" would probably vary little from season to season. The longline requires a great amount of time for deployment and retrieval, and baited hooks are easily picked clean by porgies and snappers. Sampling time could be spent more efficiently by sampling with trawl or rod and reel. Future sampling efforts should not include vertical longlines.

Juvenile Fish Sampling:

The benthic juvenile fish sled was employed to capture juvenile fishes associated with hard bottom areas. Unfortunately, the sled was lost at the first station and no data were collected. However, small try nets with a 1-mm mesh liner sewn into the bag would be an effective replacement of the epibenthic sled for capturing juvenile fish. Robins and Colin (1979) used 3-m try nets over untrawlable bottom to collect small (30 - 40 mm) fishes. Gear loss was high but they were successful in obtaining fishes. Several nets might be lost; but the cost per net is minimal and would be worth the expense, especially if diving efforts to collect small adult and juvenile fishes were not attempted.

RECOMMENDATIONS FOR FUTURE STUDIES

Quantitative community studies of reefs are extremely difficult and even in shallow, tropical reefs (which have received the most study) there are severe constraints in interpretation of data due to sampling problems. The techniques of soft bottom benthic ecologists cannot be employed successfully on reefs, and most studies of reefs have used methods adapted from those used by terrestrial plant ecologists. The most important limitations are presented by (1) the nonhomogeneous physical environment produced by the hard, three-dimensional physical structure of reefs, (2) the great diversity and abundance of reef organisms, and (3) the extreme patchiness of the distribution of algal, invertebrate, and fish species. The results of the application of mathematical techniques which assume representative sampling of entire communities and complete sampling of any single taxon should be viewed with suspicion until the validity of the underlying assumptions has been tested adequately. For these reasons we recommend that future live bottom studies off the North Carolina coast concentrate on qualitative descriptions and functional studies of the organisms inhabiting these reef-like structures.

Regarding potential impacts of man's activities, one of the most important questions which should be addressed in greater detail is the importance of these reefs to pelagic fisheries over the reefs and to demersal fishes of adjacent soft bottom habitats. Studies should address problems of pathways and rates of transfer of energy and cycling of materials into, within, and out of the reef systems. Efforts should be made to elucidate the major pathways by which primary production is transferred to the top carnivores, many of which are commercially important reef and pelagic fishes. In addition, studies should be done to determine whether pelagic fishes depend on live bottoms (at some stages in their life cycles) and the extent to which live bottom demersal fish use adjacent soft bottom areas for resources. Finally, studies concerning the rates and pathways of recruitment of algae, invertebrates, and particularly demersal reef fishes should be attempted and should include a comparison of larval drift from the south via the Gulf Stream as opposed to within-latitude recruitment as a source of organisms for maintaining these communities.

Research efforts directed toward the problems outlined above appear to offer a greater chance of predicting potential impacts of man's activities on live bottoms off North Carolina than do efforts at quantitative community descriptions which require as yet unrefined techniques.

In addition to changes in the type of future research efforts, an extension of the depth zones included in the live bottom study is recommended. Although by definition the outer continental shelf ends at the 100 m contour, the live bottom communities and the commercially important fisheries they support do not end there. A significant snapper/grouper fishery continues well beyond the 100-m contour to a depth of 200 - 300 m. Several commercially important species (vermilion snapper, red porgy, speckled hind, snowy grouper and grey tilefish) are caught in numbers well beyond the 100-m contour. Beyond 300 m the biological characteristics of live bottoms are relatively unknown. Extension of studies to depths greater than 100 m is particularly important in light of recent oil lease sales in deeper waters on the southeastern continental slope.

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In writing the report E. Barber was responsible for hydrographic and weather observations and parts of the introduction and sampling approach and methods chapters. She also provided valuable editorial assistance for the entire report. T. Handsel aided R. Matheson in preparation of chapters on the nektonic community, food habits and trophic relationships of fishes, and sampling methods associated with fishing activities. In addition, he provided methodology evaluation for fishing gear. P. Krikorian aided P. Peckol in preparation of chapters on sampling approach and methods, physical characterization, and the epibenthic community. She also prepared all figures in the report. R. Matheson was responsible for chapters on the nektonic community and food habits and trophic relationships of fishes; P. Peckol was responsible for chapters on sampling approach and methods, physical characterization, and benthic community. W. Kirby-Smith was responsible for the introductory chapters, impact/enhancement sections, conclusions, and methodology evaluation and recommendations. Following review of the draft report by the Bureau of Land Management, J. Ustach provided valuable assistance in revision of the report. N. J. Buck, manuscript typist, cheerfully persevered through the many drafts of this report to produce the final copy.

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